

# Astronomy<sup>®</sup>

THE WORLD'S BEST-SELLING ASTRONOMY MAGAZINE /// MARCH 2026

## STAR-STRUCK TWICE

The tale of Meteor Crater and its long-lost sibling

### PLUS:

- HOW TO RUN THE MESSIER MARATHON
- THE ART OF THE SINGLE-SHOT ASTROIMAGE
- LIFE'S BUILDING BLOCKS AT ENCELADUS
- WEBB SPIES DUSTY DISKS BIRTHING PLANETS
- OBSERVABLE SPACE'S CDK 14 REVIEWED

**BONUS  
ONLINE  
CONTENT  
CODE p. 3**



The astronomy book  
everyone will want!

# WEBB'S COSMOS

Images and Discoveries from the  
James Webb Space Telescope

by Marcin Sawicki

Written by a research astronomer  
involved with the Webb for two  
decades, this is a splendid album  
of almost 300 pictures.

But also, a clear explanation of  
why the Webb, using infrared  
imaging, detects far  
more celestial objects  
— clearer and farther  
away in distance and  
time.

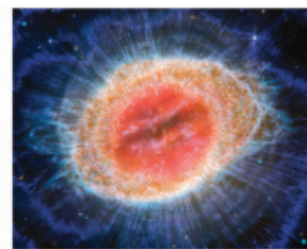
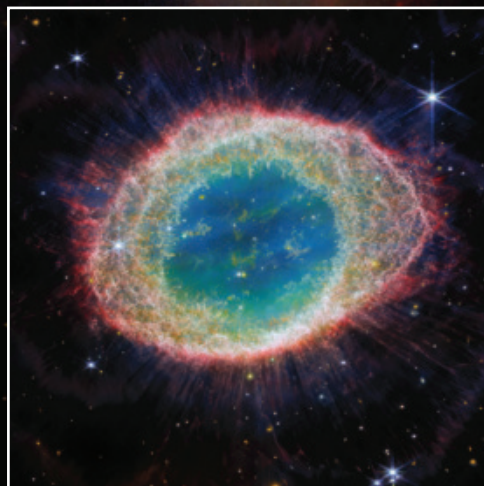
Up to date and full of  
value, an important  
book!



304 pages in glorious color  
large format hardcover  
available in November

*Hubble*

*Webb*



**UP TO THE HINGE**  
Webb offers new, unprecedented views of the Ring Nebula. This is a close-up of what  
you could probably see with a small telescope. The Ring Nebula is a glowing ring of gas  
and dust, seen edge-on. It is a remnant of a star that has died. The Ring Nebula is  
seen edge-on, showing a bright blue center surrounded by a ring of orange and red.  
The Ring Nebula is a glowing ring of gas and dust, seen edge-on. It is a remnant  
of a star that has died. The Ring Nebula is seen edge-on, showing a bright blue  
center surrounded by a ring of orange and red. The Ring Nebula is a glowing  
ring of gas and dust, seen edge-on. It is a remnant of a star that has died.  
The Ring Nebula is seen edge-on, showing a bright blue center surrounded by a  
ring of orange and red. The Ring Nebula is a glowing ring of gas and dust,  
seen edge-on. It is a remnant of a star that has died.

★ (starred review) “Stunning... the images offer unparalleled detail and clarity.” —*Booklist*

At bookstores and online

Proudly published by **FIREFLY BOOKS**  
fireflybooks.com

**4 Online Content Code: ASY2603**

Enter this code at [www.astronomy.com/code](http://www.astronomy.com/code) to gain access to web-exclusive content.

# CONTENTS

36

## FEATURES

14

### Enceladus' ocean holds building blocks of life

Analysis of Cassini data suggests organics detected in Enceladus' icy plumes could have been born through hydrothermal activity.  
**BROOKS MENDENHALL**

### 18 COVER STORY Star-struck twice

Against astronomical odds, twin shards of debris separated by a planetary collision half a billion years ago fell to Earth just a few dozen miles apart.  
**DAVID A. KRING**

26

### From dust to planets

JWST makes the clearest observations yet of an edge-on protoplanetary disk.  
**RICHARD TALCOTT**

28

### Sky This Month

Early morning lunar eclipse.  
**MARTIN RATCLIFFE AND LISTER LING**

30

### Star Dome and Paths of the Planets

**RICHARD TALCOTT;**  
ILLUSTRATIONS BY ROEN KELLY

36

### Run the Messier Marathon

All you need to complete this classic list is a good telescope, a clear sky, and energy.  
**MOLLY WAKELING**

40

### The art of the single-shot astroimage

Here's how to carefully plan a single exposure to showcase your skill.  
**SOUMYADEEP MUKHERJEE**

46

### Observable Space's CDK 14 can capture your cosmos

Superb optics, top-notch engineering, and a relatively small footprint make this scope a winner. **TONY HALLAS**

50

### Ask Astro

Why craters are round, how black holes make magnetic fields, the view of Earth from Mars, and colliding galaxies.

MARCH 2026

VOL. 54, NO. 3



## ON THE COVER

The meteorite that carved out Meteor Crater had a sister; it impacted Earth many years later, but a surprisingly small distance away. **PETER DI BARTOLOMEO**

## IN EVERY ISSUE

From the Editor 4

Astro Letters 6

Observing Basics 48  
**MOLLY WAKELING**

New Products 49

Advertiser Index 49

Reader Gallery 54

Breakthrough 58

7

## ASTRONEWS

Everything you need to know about the universe this month: NASA spacecraft image Comet 3I/ATLAS, how light pollution affects Earth's carbon budget, winds on the giant planets explained, and more.



## ONLINE FAVORITES

Go to [www.Astronomy.com](http://www.Astronomy.com) for info on the biggest news and observing events, stunning photos, informative videos, and more.



### The Space Store

Perfect gifts for your favorite science geeks.



### Trips and Tours

Travel the world with the staff of *Astronomy*.



### Sky This Week

A daily digest of celestial events.



### Ask Astro Archives

Answers to all your cosmic questions.

*Astronomy* (ISSN 0091-6358, USPS 531-350) is published monthly by Firecrown Media Inc., 405 Cherry Street, Chattanooga, TN 37402. Periodicals postage paid at Chattanooga, TN and additional mailing offices. **POSTMASTER:** Send address changes to *Astronomy*, PO Box 850, Lincolnshire, IL 60069.

AT TOP: MOLLY WAKELING.  
ONLINE FAVORITES, LEFT TO RIGHT:  
*ASTRONOMY*: WILLIAM ZUBACK; AARSTUDIO/  
DREAMSTIME.COM; ALLEXANDAR/DREAMSTIME.  
COM; SRIPFOTO/DREAMSTIME.COM



# Take your shot



I shot this nightscape of Half Dome with a Fujifilm X-E3 mirrorless camera and an 18–55mm zoom lens at 28mm, taking an 8-minute exposure at f/2.8 and ISO 400.

MARK ZASTROW. BELOW: REBECCA ISIJWARA



Last fall, I had the chance to hop in a car with a photographer friend for a classic American road trip — a week from Seattle to Los Angeles, with an inland detour to Yosemite National Park.

Some might prefer road tripping in the summer, basking in the longer days. But Becky and I quickly came to appreciate late October's earlier nightfalls. We could scout out a landscape to shoot sunset, get in some dark-sky visual and smartscope observing — Comet Lemmon (C/2025 A6) was in full splendor — and still make it back to town for a bite to eat before the kitchens closed.

One chilly night as we stood atop Glacier Point, setting up our cameras and gazing at the starry sky above Yosemite Valley, I thought of a story you'll read in this issue by Soumyadeep Mukherjee about shooting single-exposure nightscapes (page 40). He doesn't just describe how to take such shots artfully; he also makes the case for why everyone

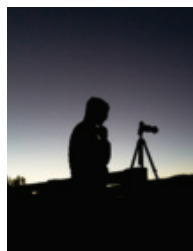
should give it a try. After all, from a technical standpoint, it's the simplest form of astrophotography. No star tracker, no stacking, just set up a tripod and press the shutter. Anyone can do it — even me.

The 8-minute exposure I took at Glacier Point is far from technically perfect, and is filled with airplane and satellites streaks. But those imperfections also make it a personal record of those eight minutes of photons that could never be re-created, and one that I'm grateful to have. If you've ever thought astrophotography was too technically demanding or out of reach, I hope you'll read Soumyadeep's story and give it a go.

By the way, if you're a longtime reader, you'll be familiar with the work and writing of planetary geologist David A. Kring of the Lunar and Planetary Institute in Houston. He's led sample analyses for the team that discovered the Chicxulub crater, formed by the impact that ended the reign of the dinosaurs. He's also one of the world's foremost experts on Meteor Crater. And in our cover story (page 18), he has a tale to tell about a pair of meteorites. One of them gouged out that famous crater in Arizona, and one of them landed much more recently, and was recovered and buried by Hopi ancestors.

David's story isn't just about the cosmic coincidence — it's also about an ancient desert landscape and the people that inhabited it. It's an enthralling narrative, and I hope you enjoy it.

Mark Zastrow  
Editor-in-Chief



Follow Mark on

Facebook:  
[facebook.com/mark.zastrow](https://facebook.com/mark.zastrow)

X:  
[@markzastrow](https://twitter.com/markzastrow)  
Instagram:  
[@markzastrow](https://instagram.com/markzastrow)

## FOLLOW ASTRONOMY



[facebook.com/AstronomyMagazine](https://facebook.com/AstronomyMagazine)  
[twitter.com/AstronomyMag](https://twitter.com/AstronomyMag)  
[youtube.com/user/AstronomyMagazine](https://youtube.com/user/AstronomyMagazine)  
[instagram.com/astromagazine](https://instagram.com/astromagazine)

# Astronomy

**Editor-in-Chief** Mark Zastrow  
**Assistant Design Director** Kelly Katlaps

## EDITORIAL

**Senior Production Editor** Elisa R. Neckar  
**Senior Editor** Alison Klesman  
**Associate Editor** Michael E. Bakich  
**Staff Writer** Brooks Mendenhall  
**Editor Emeritus** David J. Eicher

## ART

**Illustrator** Roen Kelly  
**Production Director** Kelly Kramer Weekley  
**Production Specialist** Jodi Jeranek

## CONTRIBUTING EDITORS

Bob Berman, Adam Block, Glenn F. Chaple Jr., Martin George, Tony Hallas, Phil Harrington, Korey Haynes, Alister Ling, Stephen James O'Meara, Martin Ratcliffe, Raymond Shubinski, Richard Talcott, Molly Wakeling

## EDITORIAL ADVISORY BOARD

Buzz Aldrin, Marcia Bartusiak, Jim Bell, Timothy Ferris, Alex Filippenko, Adam Frank, John S. Gallagher III, Daniel W. E. Green, William K. Hartmann, Paul Hodge, Edward Kolb, Stephen P. Maran, Brian May, S. Alan Stern, James Trefil

## Firecrown

**Chief Executive Officer** Craig Fuller  
**Chief Revenue Officer** Jonathan Keller  
**Executive Vice President, Media Sales** Preston Brown  
**Chief Operations Officer** Nicole McGuire  
**Chief Financial Officer** Tripp Thurston  
**Vice President, Finance/Controller** Amanda Joyce  
**Vice President, Creative** Barry Carpenter  
**Group President, Hobby Division** Nicole McGuire  
**Group President, Aviation Division** Ryan Ewing  
**Group President, Marine Division** David Carr  
**Editorial Director** Kaylee Nix  
**Vice President, General Counsel** Darren Caputo  
**Human Resources Director** Suzie Matoh

## ADVERTISING DEPARTMENT

**Advertising Representative** Kristi Rummel  
**Phone** (608) 435-6220  
**Email** [kristi.rummel@firecrown.com](mailto:kristi.rummel@firecrown.com)

## RETAIL TRADE ORDERS AND INQUIRIES

Selling *Astronomy* magazine or products in your store:  
**Email** [terri.meunier@firecrown.com](mailto:terri.meunier@firecrown.com)

## CUSTOMER SALES AND SERVICE

**Phone** (877) 246-4835  
**Outside U.S. and Canada** (847) 313-3921  
**Customer Service** [AstronomyMagazine@Omeda.com](mailto:AstronomyMagazine@Omeda.com)

## CONTACT US

**Ad Sales** [adsales@astronomy.com](mailto:adsales@astronomy.com)  
**Ask Astro** [askastro@astronomy.com](mailto:askastro@astronomy.com)  
**Books** [books@astronomy.com](mailto:books@astronomy.com)  
**Letters** [astronomyeditorial@astronomy.com](mailto:astronomyeditorial@astronomy.com)  
**Products** [products@astronomy.com](mailto:products@astronomy.com)  
**Reader Gallery** [readergallery@astronomy.com](mailto:readergallery@astronomy.com)

For reprints, licensing, and permissions:  
PARS International at [www.parsintl.com](http://www.parsintl.com)

Copyright © 2026 Firecrown Media Inc., all rights reserved. This publication may not be reproduced in any form without permission. Printed in the U.S.A. Allow 6 to 8 weeks for new subscriptions and address changes. Single copy: \$6.99 (U.S.). Print + digital subscription rate: U.S.: 1 year \$58.95. Canadian: Add \$12.00 postage. Canadian price includes GST, payable in U.S. funds. All other international: Add \$22.00 postage, payable in U.S. funds, drawn on a U.S. bank. BN 12271 3209 RT. Not responsible for unsolicited materials.



**FIRECROWN**





O<sub>(atomic)</sub>  
630nm  
200–300+ km



# Sunshine at night.

(Sunscreen optional)

Incoming Charged Particles

N<sub>2</sub><sup>+</sup>  
427.8nm  
80–120 km

O<sub>(atomic)</sub>  
557.7nm  
120–300 km

Join solar physicists Dr. Mark Miesch and Dr. Sarah Gibson at Lazy Bear Lodge for a Solar Science Adventure of a lifetime.

# Find yourself — in Canada's *Real North*.

[lazybearlodge.com/realnorth](http://lazybearlodge.com/realnorth)





Images from Apollo 17 show a rougher lunar terrain than other Apollo missions explored. NASA

## How to draw the Moon

I have always enjoyed seeing surface illustrations of the Moon since the 1950s. Almost without exception, they show foreground images of craggy rock walls and pinnacles, as does the October issue on the cover and page 13. I cannot recollect ever seeing such images from the Apollo astronauts' photos from the surface.

Everything looks "soft," rounded and very pillowlike, with the rare exception of large boulders.

Are illustrators still caught up in classical images of the Moon? Or are there photographic images similar to this month's illustration? —**Eric Moore**, Maple Grove, MN

**Illustrator Michael Carroll responds:** Thanks for the thoughtful question, Eric. You are correct about the Apollo sites being dominated by gentle slopes and softened landforms. However, if we look at the most rugged areas, especially at the Apollo 16 and 17 sites, rocks and jagged boulders become abundant. This gives the artist a range of forms to choose from. When it comes to the south polar region, geologists tell us that we may expect

even rougher regions. That pesky Moon dust will still be everywhere, but as an artist my goal was to portray the explorers in a crater that communicated something new and other, while still basing the general forms on Apollo, Soviet, and Chinese surface images (and orbital images like those from the Lunar Reconnaissance Orbiter). Areas with deposits of water may well display new forms, perhaps something like the rocky outcrop at the foreground right of my painting. In the end, we space artists love the challenge of pushing the visual envelope while constrained within the bounds of solid science.

## Science for nonscientists

I've been catching up on *Astronomy* issues and stumbled on an article that suited my not-an-astronomer perspective. Will you please forward to Ashley Balzer Vigil my compliments on her August 2025 piece, "Did Earth once have a ring?" She did a wonderful job explaining what I'm sure could have been seriously math-dense in a way that an intelligent nonscientist understood. And finally, please tell Roen Kelly that it was her illustration of Earth under bombardment by ring debris that first attracted me to Vigil's article. —**Matthew Leveque**, Knoxville, TN

→ We welcome your comments via email to [astronomyeditorial@astronomy.com](mailto:astronomyeditorial@astronomy.com). Please include your name, city, state, and country. Letters may be edited for space and clarity.

## ScopeBuggy

- For use with most tripods, DOBs and piers
- 10" Pneumatic tires for soft ride
- Load tested to 600+ pounds
- Assemble & disassemble in minutes
- Adjustable rear axle height (1½" to 7")
- Ideal for scopes up to 36"
- One person can quickly and easily move any sized scope

**STILL #1**

**\$345.00\***

Plus S&H  
Approx. \$70 Shipping  
USA

\*Subject to change



Patent Pending

SCOPEBUGGY  
P.O. BOX 834  
Elephant Butte, NM 87935

**915-443-9010**

[www.ScopeBuggy.com](http://www.ScopeBuggy.com)



**SNOW KING**

**OBSERVATORY & PLANETARIUM**

Jackson, Wyoming - [www.skobservatory.com](http://www.skobservatory.com)



## SNAPSHOT

# A DUSTY SCENE

Infrared view shows warm young suns shining through cold dust and gas.

The European Space Agency's (ESA) Euclid telescope launched in 2023 to study the composition and structure of our universe. Although largely tasked with mapping distant galaxies, Euclid has also returned stunningly detailed views of vistas much closer to home, including this shot of a portion of the dark cloud LDN 1641 in Orion.

Located 1,300 light-years away within the Milky Way, LDN 1641 is a cold, dusty cloud complex perfect for birthing new stars. Viewed in infrared light, as captured by Euclid's Near-Infrared Spectrometer and Photometer, young stars appear scattered throughout the orangey-brown cloud. In visible light, the dust would block these stars, but infrared instruments pick up on their heat, rendering them visible through the cooler dust of the cloud. Outflows (magenta) emanate from several of the stars — a common occurrence in young stellar objects. The upper left region of the image has less dust, revealing background stars and galaxies far beyond LDN 1641 in the foreground. — ALISON KLESMAN

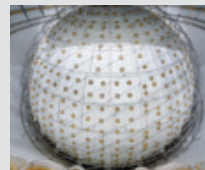


## HOT BYTES



### SPORES SCORE BIG

Moss spores can still reproduce after spending 283 days in space outside the ISS in the station's exposure-testing facility, scientists say. This marks the resilient plant as a potential key to creating self-sustaining ecosystems on other worlds.



### JUNO DELIVERS

The Jiangmen Underground Neutrino Observatory (JUNO) in Jiangmen, China, delivered its first results Nov. 19. It is now the world's most advanced neutrino detector in operation.



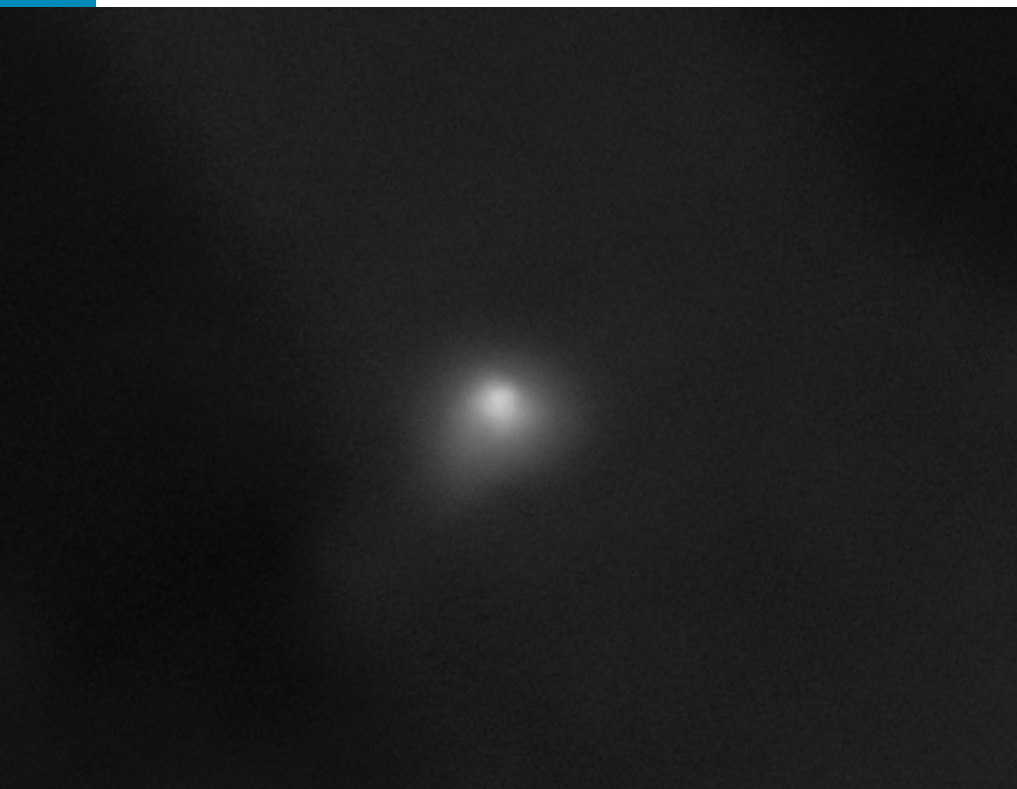
### STELLAR EXPLOSION

A team using ESA's XMM-Newton space observatory and the LOFAR radio telescope spotted a coronal mass ejection from a star other than our Sun for the first time, opening a new chapter in the study of space weather.



# NASA SPACECRAFT IMAGE INTERSTELLAR COMET 3I/ATLAS

Data from more than a dozen spacecraft highlight the capabilities of NASA's science fleet.



**BEST SHOT.** NASA's Mars Reconnaissance Orbiter's HiRISE camera captured this image of 3I/ATLAS in early October, as the comet passed Mars. Visible is the coma, a roughly spherical cloud of dust and ice created as material on the comet's surface sublimates under the heat of the Sun.

NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA

» Following the Nov. 12 end of the 43-day U.S. government shutdown, NASA hosted a livestream Nov. 19 to share spacecraft observations of Comet 3I/ATLAS, the third detected interstellar object to traverse our solar system. The unprecedented campaign captured the visitor with a combination of more than a dozen heliophysics, planetary science, and astrophysics instruments.

Observations began in early autumn, as the comet plunged toward the inner solar system to make its closest approach to the Sun Oct. 29.

## EYES IN THE SKY

The earliest shots came from NASA's Psyche, currently nearly 262 million miles (422 million kilometers) from Earth on its journey to the metal-rich asteroid 16 Psyche, which captured images of 3I/ATLAS on Sept. 8 and 9 from a distance of 33 million miles (53 million km). The photos helped astronomers refine the fast-moving comet's trajectory so other missions could more precisely target it. 3I/ATLAS entered the solar system at some 137,000 mph (221,000 km/h), but briefly sped up as it approached the Sun,

reaching a speed of about 153,000 mph (246,000 km) through the inner solar system.

The Solar Terrestrial Relations Observatory (STEREO), which studies solar storms, tracked 3I/ATLAS from Sept. 11 to Oct. 2, when the comet's position behind the Sun hid it from ground-based telescopes. These observations, along with those from the Polarimeter to Unify the Corona and Heliosphere (PUNCH) from Sept. 20 to Oct. 3 and the Solar and Heliophysics Observatory from Oct. 15 to 26, mark the first time NASA's heliophysics fleet was used to view an object from beyond our solar system. The Parker Solar Probe also observed the comet, although its data were not included in the release.

On Sept. 16, the Lucy spacecraft, en route to Jupiter's Trojan asteroids, imaged 3I/ATLAS from 240 million miles (386 million km) away. It captured the comet backlit by the Sun, revealing details in the coma and tail. But the most scientifically rich data came as the comet swept past the Red Planet. The Mars Atmosphere and Volatile Evolution (MAVEN) orbiter observed 3I/ATLAS Sept. 28. The data, showing hydrogen gas billowing off the nucleus, "will help determine the water production rate — how much water vapor is released from the comet when the comet is warmed by the Sun — which provides insight into the formation of the comet and its journey through our galaxy," said Tom Statler, lead scientist for solar system small bodies at NASA's Planetary Science Division, during the livestream. (On Dec. 6, NASA lost contact with MAVEN and was still investigating the incident at the time of this writing.)

The photo closest to the comet was



## QUICK TAKES

### IMPACTFUL DISCOVERY

Last year, on the side of a hill in Zhaoqing, Guangdong Province, Chinese researchers discovered a 2,590-foot-wide (900 meters) impact crater, the largest modern impact crater found to date. It was likely formed by a meteorite during the early- to mid-Holocene epoch.

### NEW GLENN'S NEW ESCAPE

Blue Origin's New Glenn rocket sent the twin spacecraft of NASA's Escape and Plasma Acceleration and Dynamics Explorers (ESCAPADE) mission on their journey to Mars Nov. 13, marking the rocket's second successful launch and landing of its reusable booster.

### LVK WAVES O4 GOODBYE

On Nov. 18, the international LIGO-Virgo-KAGRA collaboration completed O4, its fourth observational run since launching in May 2023. O4 comprises around 250 new gravitational-wave signals — a staggering two-thirds of the roughly 350 signals seen thus far by the network.

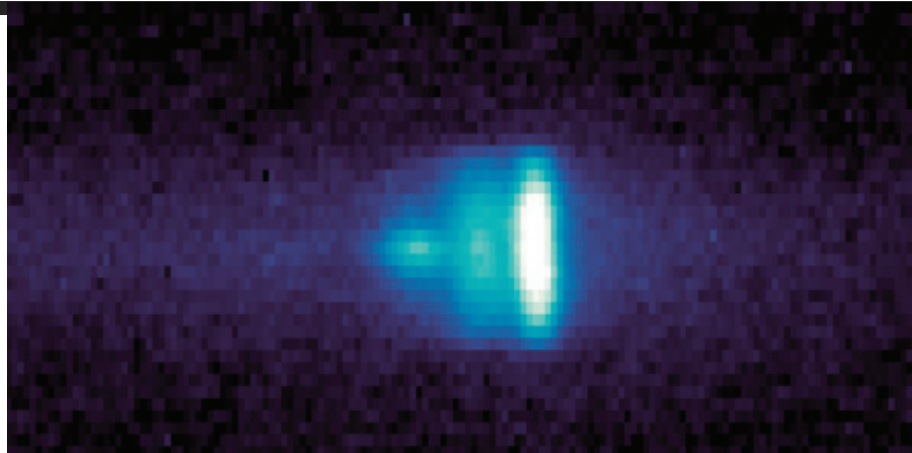
### LIGHTNING ZAPS

Recordings from the Perseverance rover's SuperCam microphone yielded the first evidence of electrical activity on the Red Planet in the form of small static sparks in dust devils and dust storms. The find informs models of Mars' climate and provides critical insight for future robotic and human exploration.

### YOU'RE GROUNDED

Airbus temporarily grounded over 6,000 of its A320 family of aircraft in November after a software glitch, reportedly stemming from solar radiation, caused a JetBlue flight to suddenly lose altitude Oct. 30, hospitalizing 15 passengers.

— B.M.



**GAS GLOW.** This image from MAVEN's Imaging Ultraviolet Spectrograph shows light generated by glowing hydrogen from three sources: the martian atmosphere (brightest signal, at right), interplanetary gas in our solar system (fainter middle signal), and 3I/ATLAS (circular signal at left). NASA/GODDARD/LASP/CU BOULDER

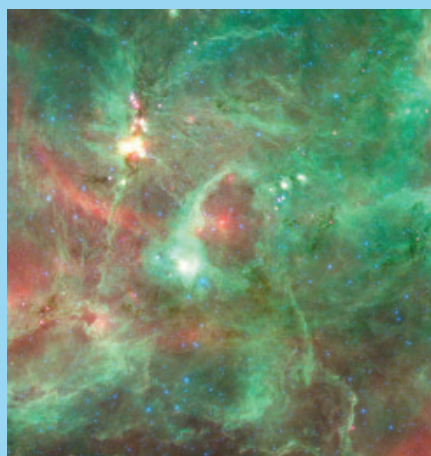
taken by the High Resolution Imaging Science Experiment (HiRISE) camera aboard NASA's Mars Reconnaissance Orbiter, which imaged 3I/ATLAS from 19 million miles (30 million km) away on Oct. 2. But perhaps the most novel observation came Oct. 4, when the Perseverance rover spotted 3I/ATLAS as a faint smudge against the martian sky — the first ever shot of an interstellar object from the surface of another world.

### A UNIQUE OPPORTUNITY

Nicky Fox, associate administrator for

NASA's Science Mission Directorate, said the chance to study the visitor on its journey through the solar system is a testament to the power and extent of NASA's science fleet. "Everything we're learning about the comet is possible because of the distribution of all of the different instruments on our spacecraft with different capabilities. And I'll note that for some of them, we've even pushed our scientific instruments beyond ... the things that they were designed to achieve to allow us to capture this amazing glimpse at this interstellar traveler," she said. — BROOKS MENDENHALL, A.K.

## DIAMOND RING IS A BURST BUBBLE



NASA/JPL-CALTECH/HARVARD-SMITHSONIAN CFA

**THE SO-CALLED DIAMOND RING** visible at the center of this infrared image of a small portion of the larger Cygnus X star-forming region has perplexed astronomers for decades. The slowly expanding ring-shaped structure of gas and dust is 20 light-years across and was formed by the intense radiation from a long-gone massive star. What makes it odd is that the Diamond Ring is truly a flat circle of gas, rather than the spherical expanding shell usually formed by such stars. A paper published Sept. 2 in *Astronomy &*

*Astrophysics* has finally explained why: It was once a spherical shell, but ultimately popped as gas escaped into the thinner regions perpendicular to the structure we now see, leaving the flattened Diamond Ring behind. The study also discovered the "diamond" is actually a foreground cluster of stars, and is not associated with the ring of gas and dust at all. — A.K.

# Light pollution reduces ecosystem carbon storage

» For decades, amateur astronomers have railed against light pollution's impact on the night sky. More recently, studies have revealed how artificial light at night (ALAN) is detrimental to sleep patterns, causing fatigue and stress in humans and animals. Now, research published Nov. 12 in *Nature Climate Change* has uncovered yet another concern: ALAN is increasing carbon released by plants and animals across continents. This reduces the amount of carbon stored in ecosystems, potentially exacerbating climate change impacts from other sources.

Using data from satellite observations and 86 carbon flux monitoring sites across North America and Europe, the authors found that ALAN increases ecosystem respiration — a natural process that happens when plants, microbes, and animals release carbon dioxide through activity and growth. They found no increase in plant photosynthesis, however, which removes carbon dioxide from the atmosphere.

"This is a widespread issue that's changing how ecosystems function, disrupting energy flows, animal

behavior, habitats, and natural patterns," said study leader Alice Johnston, senior lecturer in environmental data science at Cranfield University in the U.K., in a press release. "Put simply, brighter nights lead to greater carbon release, which is bad news for our planet."

ALAN is currently increasing by around 2 percent each year. But most climate models don't include it. The Cranfield team wants that to change. "Our findings suggest that this growing footprint could subtly but significantly shift the global carbon balance if left unaddressed," said study co-author Jim Harris, a professor of environmental technology at Cranfield.

They also cite a positive spin to the finding: "Unlike climate change, we could reduce light pollution almost overnight with better lighting design," said Johnston. "Since lighting accounts for around 15 percent of global electricity use, and growing evidence links excessive nighttime light to negative effects on human health, tackling light pollution represents a rare win-win-win for the environment, energy efficiency, and well-being." —MICHAEL E. BAKICH



**BRIGHT LIGHTS.** Artificial light at night increases the amount of carbon released by plants and animals into the atmosphere, potentially impacting our efforts to reduce the effects of climate change. AHMAD PISHNAMAZI/UNSPLASH



## A PEEP AT APEP

Four shells of dust are visible around the binary Wolf-Rayet star system Apep, imaged here by JWST. Earlier observations with other telescopes showed only one shell. The final image is a composite with blue, green, and red hues assigned to separate infrared wavelength ranges to help distinguish the system's unique architecture. JWST's Mid-Infrared Instrument captured Apep, named for the Egyptian serpent deity of chaos, in incredible detail, revealing previously unseen layers of glowing red-orange carbon dust. The shells are produced as material is ejected during 25-year periods when the stars pass close to one another as part of their 190-year orbit. What's more, combined JWST and Very Large Telescope data confirm the system, located 8,000 light-years away in the constellation Norma, actually contains three stars. The third, a massive supergiant, cuts holes into the dusty shells as it orbits. —B. M.

NASA, ESA, CSA, STScI; SCIENCE: YINJIAO HAN (CALTECH), RYAN WHITE (MACQUARIE UNIVERSITY); IMAGE PROCESSING: ALESSIA PAGANI (STScI)





**RIDE HOME.** A Long March 2F rocket booster, such as the one pictured here for the Shenzhou-13 launch in 2021, carried a return capsule to the Shenzhou-22 crew in late November. CHINA NEWS SERVICE, CC BY 3.0, VIA WIKIMEDIA COMMONS/HTTPS://WWW.YOUTUBE.COM/WATCH?V=ZCDLARISRBG

## Chinese crew temporarily stranded in space

**THE SAFE RETURN** of the Shenzhou-20 crew on Nov. 14 brought an end to the longest single stay in orbit for any Chinese crew. The crew landed at the Dongfeng landing site in north China's Inner Mongolia Autonomous Region, ending their 204-day mission. Yet the successful homecoming immediately ushered in a new, albeit temporary, crisis. While the three taikonauts touched down safely, they left their replacements — the Shenzhou-21 crew — marooned aboard the Tiangong space station with no ride home in the event of an emergency.

The Shenzhou-21 crew docked at Tiangong Oct. 31, beginning their own six-month mission and a brief week-long overlap with the Shenzhou-20 crew. Just as the Shenzhou-20 crew was preparing to leave, they discovered a small crack in their return capsule's window glass. The Chinese Manned Space

Agency (CMSA) reported that the damage was likely the result of an impact from space debris.

CMSA analyzed the damage and concluded the capsule did not meet the safety requirements for a manned return. The agency instead decided to repurpose the newly arrived spacecraft as the transport vehicle for the outgoing crew, leaving the Shenzhou-21 crew stranded.

Thankfully for the Shenzhou-21 crew, their predicament didn't last long. The Chinese space program keeps a Long March 2F rocket and Shenzhou capsule ready at all times for emergencies like this. CMSA sent the Shenzhou-22 spacecraft (previously scheduled for launch in spring 2026) as a lifeboat for the Shenzhou-21 crew, ensuring a ride home in the event of an emergency. The Shenzhou-22 craft successfully docked with the station on Nov. 25, ending the crisis. —B.M.

**6 billion** The number of metric tons per second being accreted from its surroundings by Cha 1107-7626, a young, growing, 5- to 10-Jupiter mass rogue planet without a home star.

*Because telescopes are for one-eyed pirates*



BT 127 SD

Reviewed:



**OBERWERK** Obsessed with Binoculars® [oberwerk.com](http://oberwerk.com)

Follow us on  
**Facebook!**



GO TO

[www.Facebook.com/AstronomyMagazine](http://www.Facebook.com/AstronomyMagazine)

### Fundamentals First Fund

An ETF  
Symbol **KNOW**  
Your money  
Carefully managed



#### Abstract

The Fundamentals First Fund, an ETF, is part owner of approximately 100 publicly traded worthy companies, and it owns publicly traded debt. These worldwide companies are vital, important, useful, or just plain nice to have around, and most have been pursuing their business course for decades. We individually select these companies with care and in a manner as to spread our risk so that no single company event can cause more than a bruise. Mason Capital has managed money this way for more than three decades. If you are more specifically interested in who we are, how we do it, and how you might participate, read on.

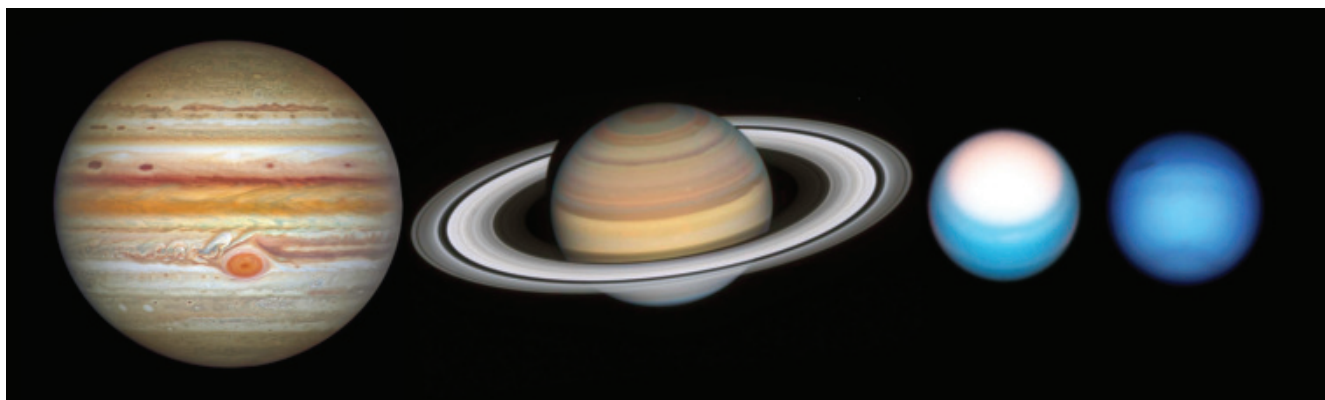
[www.FundamentalsFirstFund.com](http://www.FundamentalsFirstFund.com)

(Our Website Has a Lot About Us)

|                          |         |
|--------------------------|---------|
| 2/21/24 IPO Market Open: | \$10.00 |
| 11/28/25 Market Close:   | \$11.36 |
| Dividends Paid:          | \$ 0.28 |

*Investors should consider the investment objectives, risks, charges and expenses carefully before investing. For a prospectus or summary prospectus with this and other information about the Fund, please call 617-228-5190 or visit our website at [www.fundamentalsfirstfund.com](http://www.fundamentalsfirstfund.com). Investments involve risk. Principal loss is possible. Quasar Distributors LLC.*

# NEW MODEL EXPLAINS GIANT PLANETS' WINDS



**A STUDY PUBLISHED OCT. 10** in *Science Advances* proposes a solution to a giant-planet mystery that scientists have pondered for decades: Why do the ferocious jet streams at the equators of Jupiter and Saturn roar eastward — in the same direction as those planets rotate — while the same winds on Uranus and Neptune run westward, against their planets' spin?

The prevailing assumption was that the opposite flows must be due to different mechanisms. However, the authors note, the planets are so similar — all four receive little sunlight, possess moderate internal heat sources, and rotate rapidly — that a single underlying process seems more likely.

Using hydrodynamic models

**IN THE WIND.** These simulations show the eastward-flowing (red) jets on Jupiter and Saturn (left) and westward-flowing (blue) jets on Neptune and Uranus. The Greek letter omega ( $\Omega$ ) is the planet's direction of rotation. The left half of each globe shows average wind direction and speed, while the right half shows the "conveyor belt" system of individual convection columns responsible for the overall flow. KEREN DUER-MILNER ET AL., *SCIENCE ADVANCES*, 2025. DOI: 10.1126/SCIADV.ADS8899 (CC BY-NC)

to simulate the planets' atmospheres, the team discovered that powerful convection cells (rising and sinking currents of gas) organize into tilted columns near the equator under the influence of the planet's rotation. These columns, which transport heat from the planet's interior to its outer layers, act like rollers driving a giant conveyor belt, propelling the powerful jet streams.

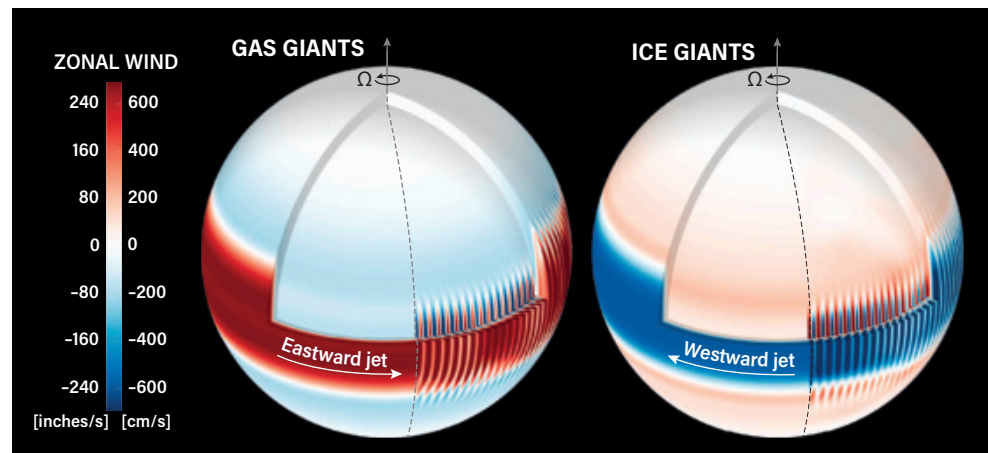
Further, the model revealed a critical point where, under nearly identical conditions, an atmosphere will settle into one of two states: eastward or westward winds. In atmospheres with deep convective regions like Saturn's, the

**FAMILY PHOTO.** The solar system's giant planets — Jupiter, Saturn, Uranus, and Neptune (from left to right, imaged here by the Hubble Space Telescope) — are all similar, yet have varying jet stream directions. New research suggests a reason why. NASA, ESA, A. SIMON (GODDARD SPACE FLIGHT CENTER), AND M.H. WONG (UNIVERSITY OF CALIFORNIA, BERKELEY) AND THE OPAL TEAM

model produced only eastward winds; when convection is shallow, the model produced only westward winds. And on worlds with midrange convective layers — such as Jupiter, Uranus, and Neptune — both outcomes are equally possible. There, the atmosphere settles into whichever state is established first due to other factors, such as random chance

or conditions during the planet's formation.

The implications stretch beyond our own cosmic neighborhood. "Understanding these flows is crucial because it helps us grasp the fundamental processes that govern planetary atmospheres — not only in our solar system but throughout the Milky Way," said lead author Keren Duer-Milner, a postdoctoral researcher at Leiden Observatory and Space Research Organisation Netherlands, in a press release. "This discovery gives us a new tool to understand the diversity of planetary atmospheres and climates across the universe." —B.M.





# Astronomy

# SAVE UP TO 54%

## ON 1 YEAR OF ASTRONOMY



Each year you'll receive:

- Countless observing tips ("Ask Astro!")
- Brand new Sky Guides ("The Sky This Month")
- Breaking space news and discoveries
- Understandable scientific analysis from astronomy & cosmology experts
- Breathtaking photos of the newest celestial objects
- Photo galleries showcasing our readers' best snapshots
- Unbiased reviews of all astronomical tools & equipment

AND SO MUCH MORE!

VISIT US ONLINE:  
**ASTRONOMY.COM/SUBSCRIBE**



# ENCELADUS' OCEAN

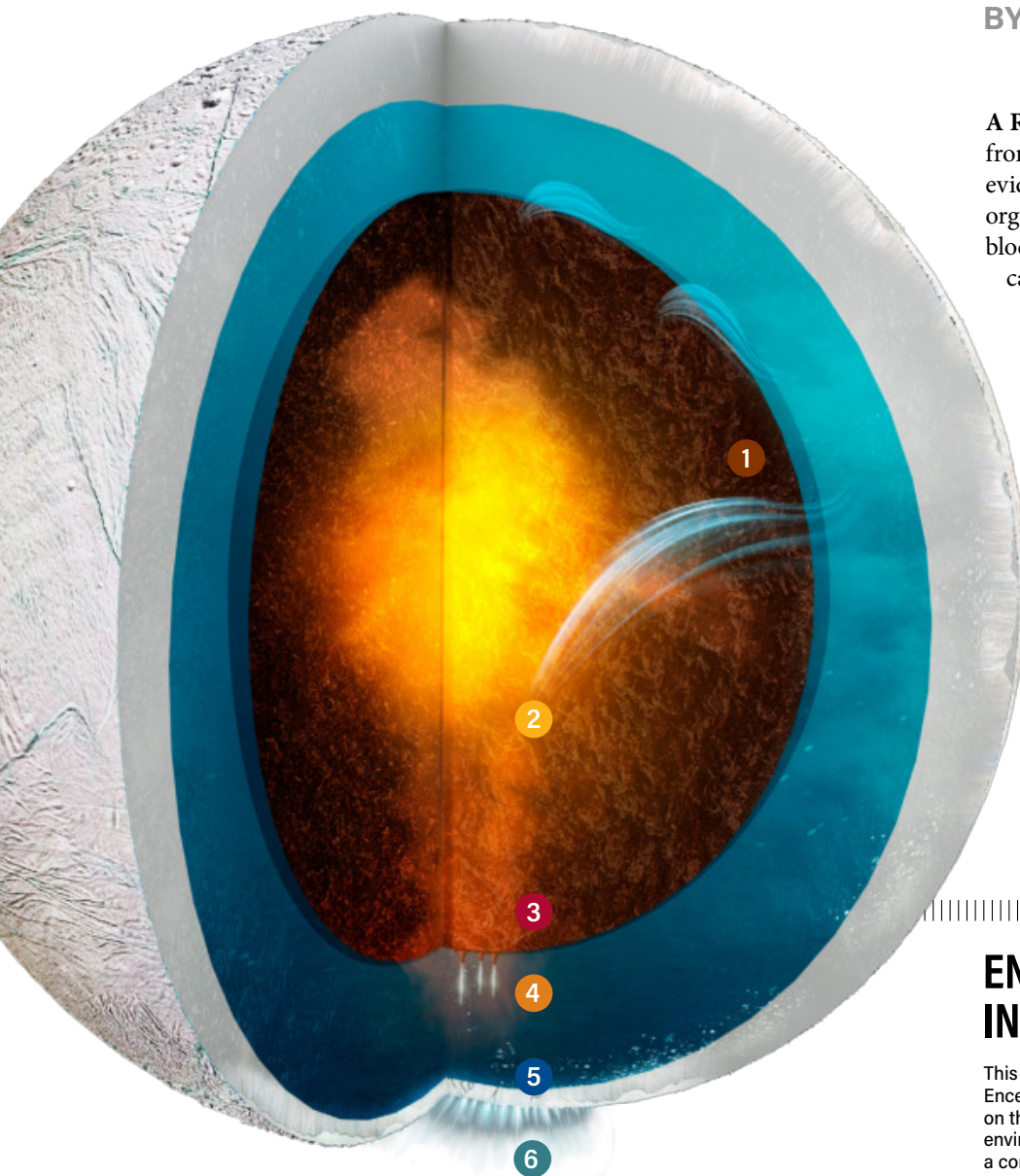
## HOLDS BUILDING BLOCKS OF LIFE

Analysis of Cassini data suggests organics detected in Enceladus' icy plumes could have been born through hydrothermal activity.

BY BROOKS MENDENHALL

**A RECENT ANALYSIS** of archival data from NASA's Cassini spacecraft provides evidence that Enceladus' ocean contains organic molecules — the key building blocks of life. This finding strengthens the case that the ocean is potentially habitable.

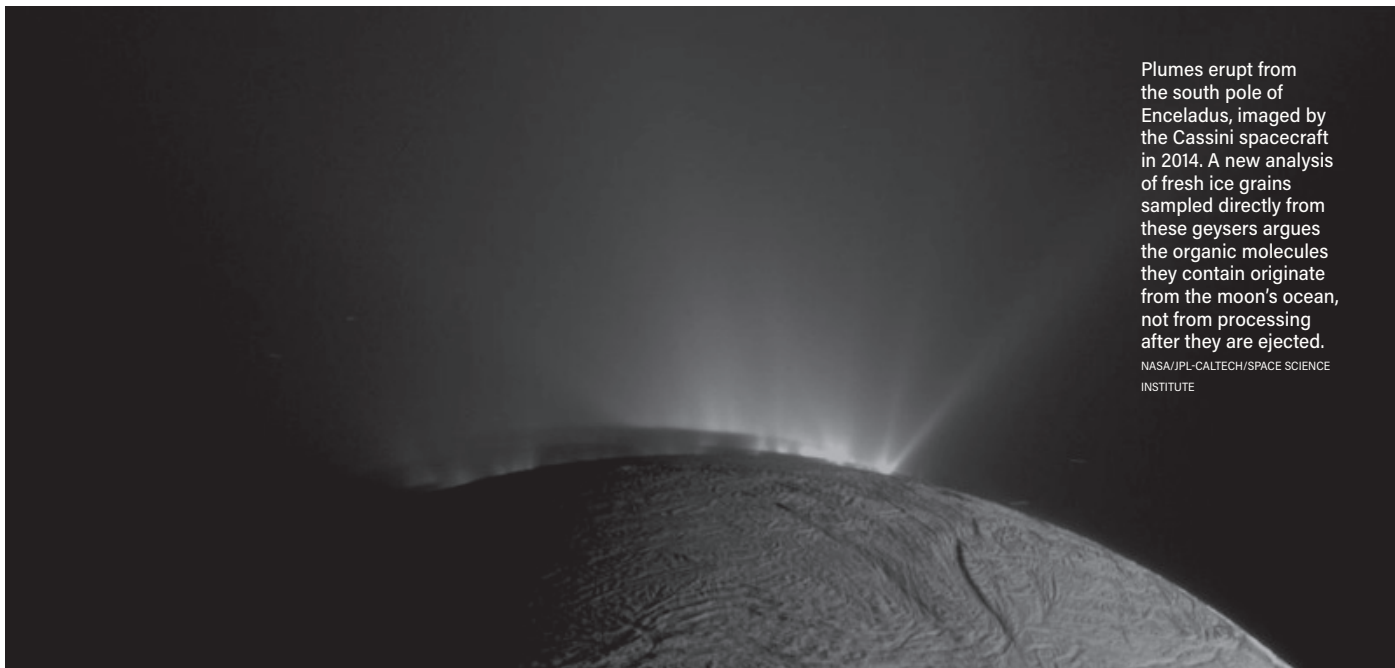
Scientists have known since 2005 that Enceladus harbors an ocean beneath its icy crust. The moon continuously vents vapor and ice grains from that ocean through surface cracks in its south polar region, creating Saturn's vast outer E ring. Organic molecules have previously been found in the E ring; however, it was unclear whether those organics formed in the ocean or in space. The ice grains in the E ring are subjected over time to high-energy radiation. Radiation striking the grains can produce organic molecules, meaning organics found



## ENCELADUS' INTERNAL STRUCTURE

This artist's impression illustrates the interior of Enceladus. Scientists believe hydrothermal activity on the ocean floor creates a warm, mineral-rich environment. A 2025 study argues this is the source of a complex brew of organic molecules found within the moon's plumes. ESA/NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE/LPI





Plumes erupt from the south pole of Enceladus, imaged by the Cassini spacecraft in 2014. A new analysis of fresh ice grains sampled directly from these geysers argues the organic molecules they contain originate from the moon's ocean, not from processing after they are ejected.

NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

in the E ring may not represent the ocean's chemical makeup.

The new study, published Oct. 1 in *Nature Astronomy*, answers this question by going straight to the source. For the first time, researchers analyzed minutes-old, fresh ice grains and found the same organics previously seen in the E ring.

What's more, the team also found organic molecules that had not yet been identified at Enceladus. These new molecules are some of the first steps in a chain of chemical reactions that lead to molecules necessary for life on Earth.

"There are many possible pathways from the organic molecules we found in the Cassini data to potentially biologically relevant compounds, which enhances the likelihood that the moon is habitable," said Nozair Khawaja, a planetary scientist at the Free University of Berlin and lead author of the paper, in a press release.

## Analyzing fresh grains

Though the Cassini mission ended in 2017, the pivotal data for this discovery were collected by the Cosmic Dust Analyzer (CDA), one of Cassini's dozen instruments. The CDA was designed to capture individual ice grains, which are smaller than grains of sand, and then analyze their composition. During its flybys of Enceladus, Cassini collected samples from the plumes erupting from fissures dubbed tiger stripes near the moon's south pole. It also collected samples from Saturn's E ring.

While the team "had already found many organic molecules in these [E ring] ice grains, including precursors for amino acids," Khawaja said, they couldn't rule out that these had been created by radiation in space after the ice was expelled from the moon.

It's also possible the organics could be created when radiation hits ice on the moon's surface, according to a laboratory

study presented by Grace Richards, a researcher at Italy's National Institute for Astrophysics, and colleagues in September 2025 at the Europlanet Science Congress and American Astronomical Society's Division of Planetary Sciences joint meeting. Their experiment simulating ices in Saturn's radiation environment produced several different organic molecules.

The Khawaja-led study, however, argues that archival Cassini data hold the answer to the origin of the organics. During the 2008 E5 flyby (the fastest of the mission) Cassini plunged directly through the plumes. The spacecraft flew through a part of the plumes with a high density of ice grains, traveling only 13 miles (21 kilometers) above the tiger stripes and collecting samples of young, fresh ice grains. The team analyzed these minutes-old grains and found the exact same organics as in the E ring. This similarity, Khawaja tells *Astronomy*, "proves that the origin of organics in ice grains is within Enceladus."

While Richards' study demonstrates that some organics can form on the moon's surface, Khawaja doesn't see this as undermining his team's results. He says that Richards' team likely exposed their ice to radiation for far longer than the minutes-old grains his team analyzed. He also notes a key difference in the chemicals themselves: The lab study

- 1 Cold ocean water seeps down into the rocky core.
- 2 The water is heated in the core and rises back toward the ocean, interacting with rocks along the way.
- 3 The heated water escapes through cracks in the ocean floor called hydrothermal vents.
- 4 Heated water and rocky material flow through the ocean toward the ice shell.
- 5 The warm water melts the ice shell.
- 6 Jets of water carrying rocky particles from the core erupt through cracks in the ice.

started with a simple set of initial conditions and created simple organics, whereas his team detected a more complex brew of molecules in the actual plumes and the E ring.

So, with enough time, radiation can produce organics on the moon's surface and within the ring grains. However, Khawaja says, radiation exposure cannot explain the specific molecules his team detected in the fresh grains. Their findings suggest the organic molecules found in the plume and thus the E ring come from the ocean's liquid water and not from reprocessing in space.

### A new chemical inventory

The results of Khawaja's study offer the clearest evidence for the oceanic origin of molecules detected in Saturn's E ring. These include aryl compounds (stable molecules built from aromatic rings, a specific type of carbon-ring structure) and various oxygen-containing compounds. One of the most significant findings, however, was the detection of organics that had not been documented at Enceladus before.

The E5 flyby's speed was key to this new chemical inventory. Its encounter speed of approximately 40,000 mph (64,000 km/h) was critical. At the mission's typical, slower encounter speeds, water molecules clump together upon impacting the CDA, forming large, so-called molecular water clusters that dominate the measurements and mask the signals of other compounds. But the high-speed impacts during E5 were energetic enough to cause the water molecules to break down into their constituent atoms as they hit the detector. This prevented clumping, erased the overwhelming signal, and cleared the path to new discoveries.

The new chemical inventory included molecules which, on Earth, act as the raw ingredients for life. The team detected alkenes, intermediates in chemical reactions necessary for the creation of other organics. They also identified esters and ethers — the first chemical steps toward lipids, which help form cell membranes. And they found evidence of oxygen- and nitrogen-bearing compounds, which are the chemical precursors of DNA and RNA.

**"There are many possible pathways from the organic molecules we found in the Cassini data to potentially biologically relevant compounds, which enhances the likelihood that the moon is habitable."**

—Nozair Khawaja, planetary scientist



Enceladus continuously supplies ice grains to Saturn's E ring (seen in this Cassini image). A new analysis argues that the complex organics found in the fresh plumes are identical to those found in the older grains of this ring, suggesting they originate in the moon's subsurface ocean. NASA/JPL/SPACE SCIENCE INSTITUTE

### A chain of discovery

The latest study builds on two decades of research from Cassini data. The chain of discovery began with the 2005 detection of the jets themselves. This led to the confirmation of a global, salty ocean in 2014, followed by evidence of hydrothermal activity in 2015. In 2018, findings proved the existence of complex organic molecules in the E ring. Now the 2025 research improves the case for Enceladus' habitability, establishing the potential oceanic origin of those molecules.

Another 2025 study, published in *Science Advances*, provides further evidence. Scientists found Enceladus is leaking heat from its north pole as well, not just through the tiger stripes at its south pole. The total heat loss from both poles almost perfectly matches the heat the

moon gains from tidal heating (the process where Saturn's gravity heats the moon's interior by stretching and squeezing it as it orbits). This balance is critical: Without enough heat, the ocean would freeze, but too much could make the environment uninhabitable. The balance suggests Enceladus is stable, and its ocean has likely been warm and liquid for a long time — a requirement for life to develop.

While Cassini provided an unprecedented look at Enceladus, its mission was limited to flybys. To learn more, a dedicated mission is necessary. The search for life on the icy moon has led to several concepts, including the Enceladus Orbilander, a hybrid orbiter-lander

concept proposed to NASA by the Johns Hopkins University Applied Physics Laboratory for launch in the late 2030s and arrival in the early 2050s. ESA has also identified Enceladus as its top target for a large-class mission as part of its Voyage 2050 plan, proposed to launch in the early 2040s and arrive a decade later. Scientists from China, too, have proposed a long-term concept featuring an orbiter, lander, and an ice-drilling robot capable of reaching depths of 3 miles (5 km).

A mission that succeeds in accessing Enceladus' subsurface ocean has a real chance of answering the profound question of whether life is exclusive to Earth. ♀

---

**Brooks Mendenhall** is staff writer of *Astronomy* and is based in Chattanooga, Tennessee.





# the space store®

## Explore the Universe

The Space Store offers an extensive selection of space mission patches, rocket and airplane models, meteorites, toys, books, and unique items from NASA, SpaceX, Boeing, and the U.S. Space Force.

Come and check out the largest retailer of NASA and space-themed collectibles, apparel, and gifts, serving enthusiasts of all ages!

**Shop now at: [TheSpaceStore.com/Shop](https://www.thespacestore.com/shop)**





# STAR-STRU



Against astronomical odds, twin shards of debris separated by a planetary collision half a billion years ago fell to Earth just a few dozen miles apart. **BY DAVID A. KRING**

**ALTHOUGH WE MAY BE** loath to admit it, there sometimes appears to be a little magic in science.

By magic, I refer to an overwhelming sense of wonder that accompanies surprising outcomes. Events over time — perhaps billions of years — can be folded



# CK TWICE



For Free Magazines visit [Sanet.st](http://Sanet.st)

together to produce a fascinating story.

This is one of those stories. It begins in the early solar system, when violent impacts shaped a small world — and ends with those same forces leaving their mark on Earth, in ways that

would astonish both modern-day scientists and the Indigenous peoples who witnessed stones falling from the sky.

## **The planetary protagonist**

The story starts nearly 4.6 billion

years ago in a molecular cloud, when a cold, dense core collapsed into a spinning disk. As hydrogen and helium were captured by a protostar, soon to be our Sun, the disk's dust coagulated into proto-planetary nuggets, the first geologic products of our solar system.

At roughly 0.75 mile (1.2 km) wide and 600 feet (180 m) deep, Meteor Crater is one of the best preserved and most visited impact craters in the world.

PETER DI BARTOLOMEO



Swirling about the Sun, they quickly grew into small planets.

Among them was a planetesimal with a diameter of about 300 miles (500 kilometers), nearly the size of the state of Arizona. This planetesimal was a mixture of rock and iron-rich metal and sulfide — the same materials found in the most primitive meteorites that fall to Earth today, in proportions that generally match those found in the Sun.

But this young world was still malleable. Radioactive elements left over from exploding stars heated the planetesimal from within, making it easier to melt during violent collisions — some of which hit with such devastating force that rock, metal, and sulfide were spewed into space, never to return.

The consequences of those collisions were imprinted on our protagonist. Its surface was pockmarked with impact craters and repeatedly fractured, producing overlapping debris fields of planetary rubble and deeper subterranean volumes of fragmented rock. Meteoritic relics of that rock have fallen to Earth and, when measured with radiometric dating, indicate two particularly large impacts occurred 3.5 million and 5 million years after the solar system formed. The earlier impact event was so powerful that it excavated a crater spanning one-third to one-half of the planetesimal's diameter.

The energy of that collision generated immense pressures that metamorphosed and melted large swaths of the planetesimal, generating a pool of molten rock and metal tens of miles in diameter. That crater lake was blanketed by a layer of rock, some of which broke away from crater walls, and some of which fell back to the asteroid from the cloud of ejected debris. This silicate-rich rock layer insulated the heated material and allowed the molten lake to cool slowly.

As it did, metal and sulfide,

being denser than the bulk magma, began to sink. A molten metal mass accumulated on the floor of the crater. That dense, off-centered slug of metal torqued the planetesimal's spin, causing it to gyrate in space. It was also insulated by 20 to 40 miles (30 to 60 km) of overlying material, so the metal cooled only around 20 to 40 degrees Fahrenheit (10 to 20 degrees Celsius) per million years, taking 50 million to 100 million years to fully crystallize.

At those slow cooling rates, the

Studies of winonaite, IAB iron meteorites, and many other types of meteorites suggest collisions became far less frequent after the first billion years of solar system history.

metallic crystals had time to grow large, up to 20 inches (50 centimeters) initially, and, upon further cooling, to millimeter to centimeter dimensions visible to the naked eye. This process produced the famous Widmanstätten texture now seen in some coarse-grained iron meteorites — geological specimens that are far older than any rock generated on Earth. They are ancient messengers of the earliest geologic processes that shaped our solar system.

### A divided world

While the floor of the crater produced spectacular silver-colored specimens of metal, the overlying silicate-rich portion of the molten lake, far larger in volume,

solidified separately. As it crystallized, the most abundant minerals to precipitate were pyroxene and olivine. Intermingled with the pyroxene and olivine were plagioclase feldspar crystals, remnant metal and sulfide that did not fully separate, and a suite of other minor minerals. It is a colorful mixture. When viewed through a petrographic microscope — a type of microscope that uses polarized light — the rock generates a stained-glass view of that 4.5-billion-year-old world. Such meteorites, now referred to as winonaite, are among the oldest planetary samples known.

Thus, the collision that reshaped the planetesimal produced two distinct layers: a beautiful, crystalline layer of rock overlying a denser layer of metal alloy. As the metal sank to the crater floor, it captured some of the rock material, producing jewel-like inclusions. These embedded rocks, which resemble winonaite, can still be found in some iron meteorites that are now classified as IAB meteorites based on their chemical composition. The inclusions are physical evidence of the common origin of these two types of meteorites.

The planetesimal was pummeled repeatedly over the next 200 million years, fracturing the crust further, mixing it with other rock, and recrystallizing portions of it, producing an increasingly complex set of textures found in some meteorites. The planetesimal may have been disrupted and reassembled during this interval of time. But that would have been only a precursor to an event that occurred approximately 4 billion years later.

Studies of winonaite, IAB iron meteorites, and many other types of meteorites suggest collisions became far less frequent after the first billion years of solar system history, so it is not surprising that the solidified metal-rich material in the planetesimal lay buried kilometers beneath the surface



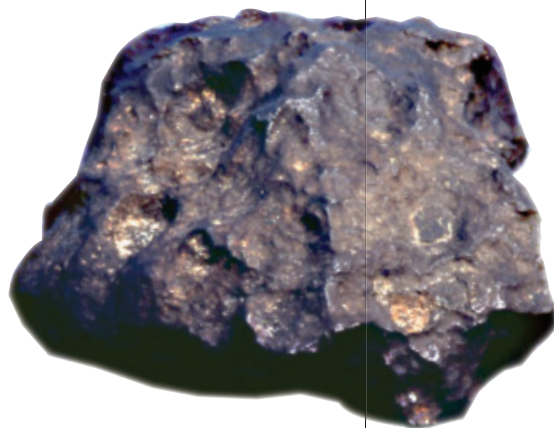
for nearly 4 billion years. A collision with another planetesimal, however, finally jettisoned debris, including the slug of metal, exposing it to cosmic radiation roughly 500 million years ago. The liberating collision was incredibly violent — and potentially disrupted a large, roughly 200-mile-wide (300 km) body about 470 million years ago, producing meteorites belonging to a common class that scientists now call L-chondrites. That disruption event is so consequential in solar system history that most shock-metamorphosed and partially-melted L-chondritic meteorites were produced at that time.

When the two planetesimals collided, shock waves rippled through both bodies. Rock was crushed and compressed, with molten material shooting through fractures before both worlds were shattered. Fragments of all sizes flowed away from the collision, cartwheeling silently into space and littering the ecliptic plane with flotsam of rock and metal.

## Two stars fall in canyon country

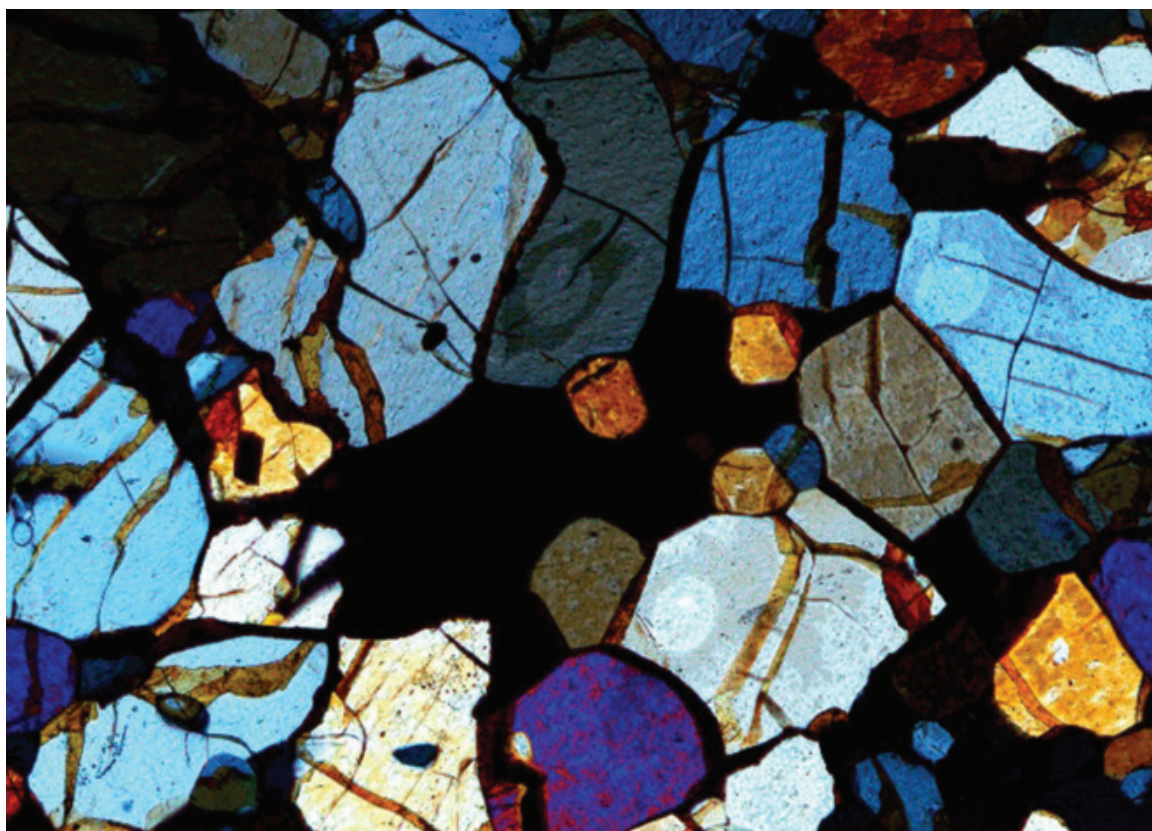
Some of that debris began to orbit the Sun on trajectories that crossed paths with Earth quickly, depositing L-chondritic meteorites and a winonaite that were later found in ocean sediments. More importantly, the Earth was showered with asteroids, producing prodigious amounts of impact craters. Although it is often difficult to link a crater to a specific type of asteroid, two craters from this period contain a weak chemical signature of L-chondrites and another crater contains the signature of an iron asteroid. Those and other asteroids collided with a prehistoric, Ordovician world flourishing with life, slamming onto land covered with moss and liverworts and splashing down in seas flourishing with animals: filter-feeding graptolites and brachiopods, scavenging and predatory animals called trilobites, and early vertebrates called conodonts.

But our block of metal took a longer route to Earth, remaining firmly ensconced within the asteroid belt for a half-billion years before it crashed to the surface 50,000 to 60,000 years ago. The region where it fell was not inhabited by humans at that time, but Ice Age mammals, like mammoths and mastodons, may have seen the asteroid streaking over the Grand Canyon. Imagine a scene at dawn, when a sun-bright bolide with a trailing plume of smoke made a blistering dive for the surface of northern Arizona. The iron mass hit with



ABOVE: Numerous fragments of the asteroid that created Meteor Crater have been found along its rim, including by Hopi ancestors. Collectively, these rock fragments are referred to as the Canyon Diablo meteorite, named for a nearby canyon.

DAVID A. KRING



LEFT: When examined under a microscope with polarized light, samples of the Winona meteorite appear like stained glass with vivid colors generated by interference effects.

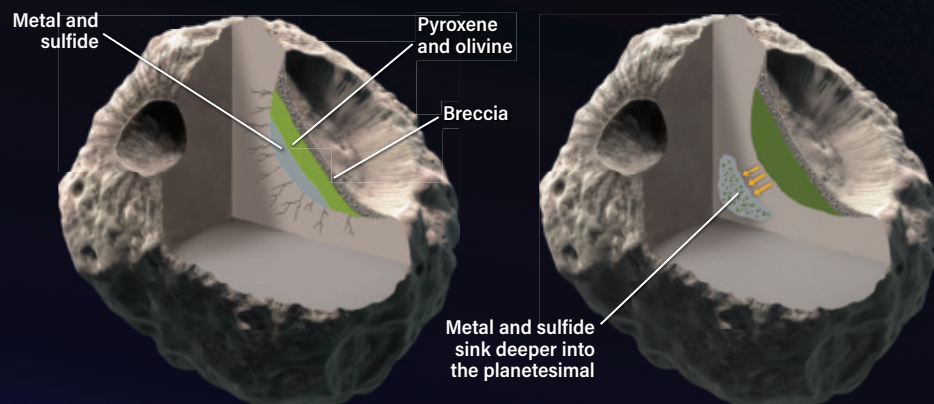
DAVID A. KRING



# A METEORITIC ORIGIN STORY

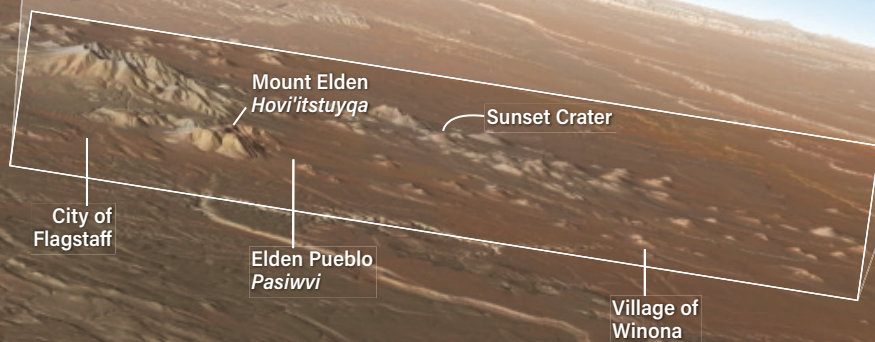
Scientists have been able to trace the history of the planetesimal that birthed both the Canyon Diablo meteorite and the Winona meteorite.

FAR RIGHT: In the first few million years after the solar system formed, the planetesimal suffered numerous collisions, becoming heavily cratered.



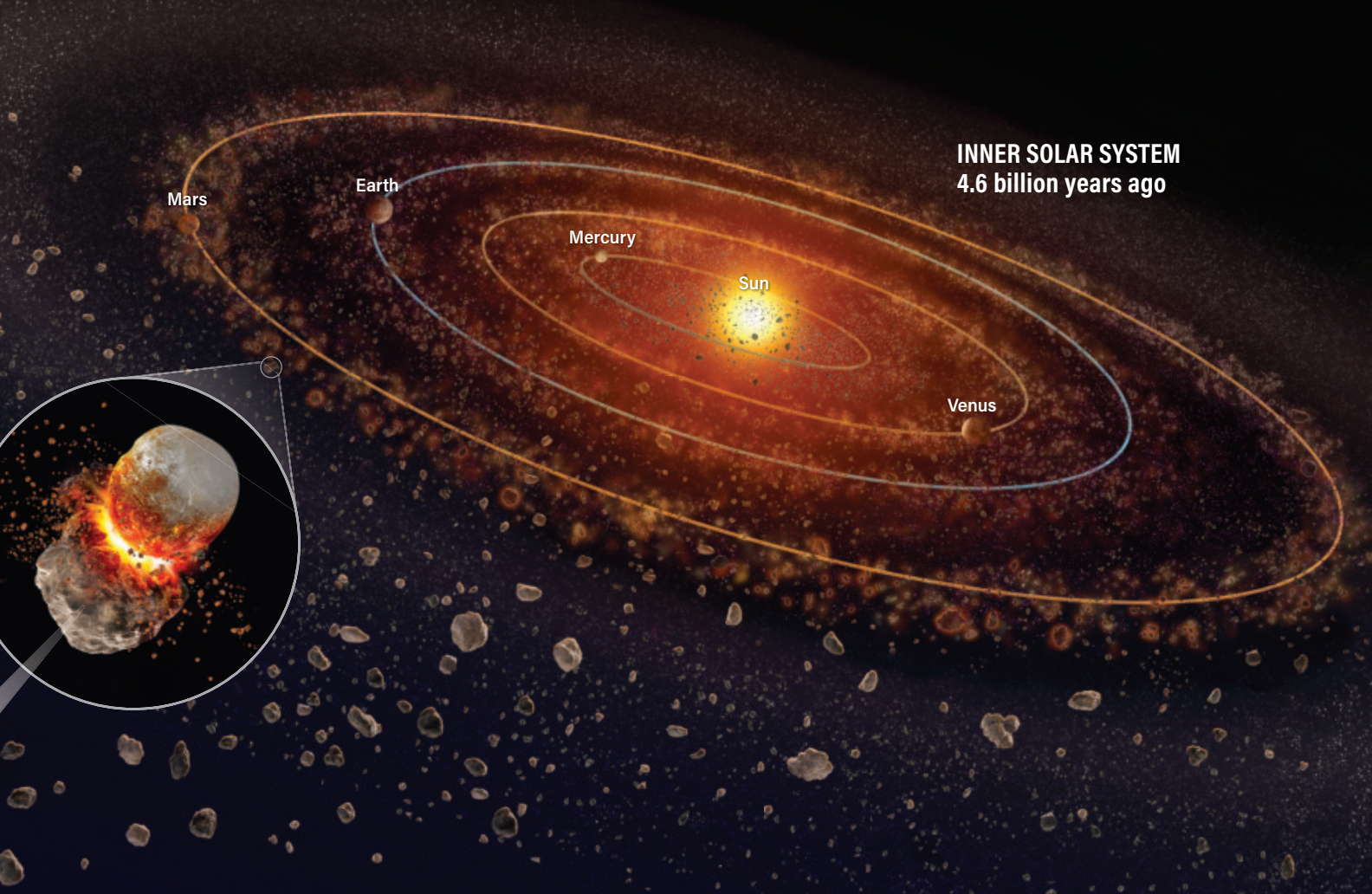
ABOVE LEFT: These impacts reshaped the planetesimal — at times, melting and metamorphosing the rock, which pooled in different layers. Scientists can now study these different rocks recovered in meteorites. This crater cross-section depicts metal and sulfide as blue, pyroxene and olivine as green, and a gray blanketing layer of breccia rocks fallen back to the asteroid post-impact and from collapsed crater walls. ABOVE RIGHT: It's possible that the metal and sulfide sank even deeper into the planetesimal, as depicted here.

VICTOR LESHYK FOR LPI/VCLSE/KRING



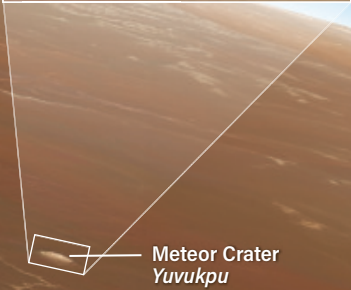
Canyon Diablo  
Ötöfsikvi





**INNER SOLAR SYSTEM**  
4.6 billion years ago

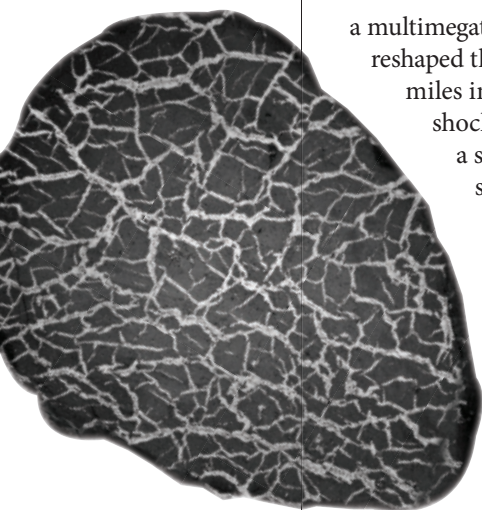
Two fragments liberated from a collision half a billion years ago both fell to Earth in modern-day Arizona within the last 60,000 years. BELOW: A two-story pueblo sits atop an ancient volcanic landscape dotted with cinder cones, where the Winona meteorite struck centuries ago, in this artist's rendering. The pueblo's residents cultivated corn and other crops in the ash-rich soil visible in the middle distance. ASTRONOMY: ROEN KELLY, BASED ON PHOTOGRAPHS PROVIDED BY DAVID A. KRING AND ARCHITECTURAL RENDERINGS BY ARCHAEOLOGIST DENNIS GILPIN OF THE MUSEUM OF NORTHERN ARIZONA





RIGHT: The Winona meteorite was excavated in 1928 from a vacated pueblo and named after the nearby town of Winona, Arizona. DAVID A. KRING

BELOW: Canyon Diablo meteorites are known for their graphite nodules, which have spectacular metal veins coursing through them. LAURENCE GARVIE, BCMS, ASU



a multimegaton blast that reshaped the ecosystem for miles in all directions. A shock wave raced over a sage and woodland steppe, followed by a supersonic air blast, while the impact explosion excavated 175 million metric tons of rock, carving Meteor Crater from the Colorado Plateau.

The first of this story's two stars had struck. Iron-rich material, produced by an impact cratering event more than 4.5 billion years ago, had found its way to Earth and, in a cosmic recycling process, produced another impact crater.

Other debris from the collisional evolution of the planetesimal still lurked in space. In particular, one fragment of the silicate-rich material that pooled and crystallized above the metal continued to zip around the Sun. That fragment eventually collided with another asteroid about 50 million years ago, exposing once-buried material to cosmic radiation.

The exposed material continued to orbit the Sun until it collided with the Earth about 900 years ago near what is now Winona, Arizona — producing the Winona meteorite, only 25 miles (40 km) from Meteor



Crater. Improbable as it would seem, two fragments of an impact crater on a nearly 4.6-billion-year-old planetesimal, liberated from that planetesimal by one or more other impact events, orbited the Sun a billion times before colliding with our planet and landing within sight of each other.

A second star had struck. And this falling star was observed by ancestors of the modern-day Hopi people.

### Ancient stargazers

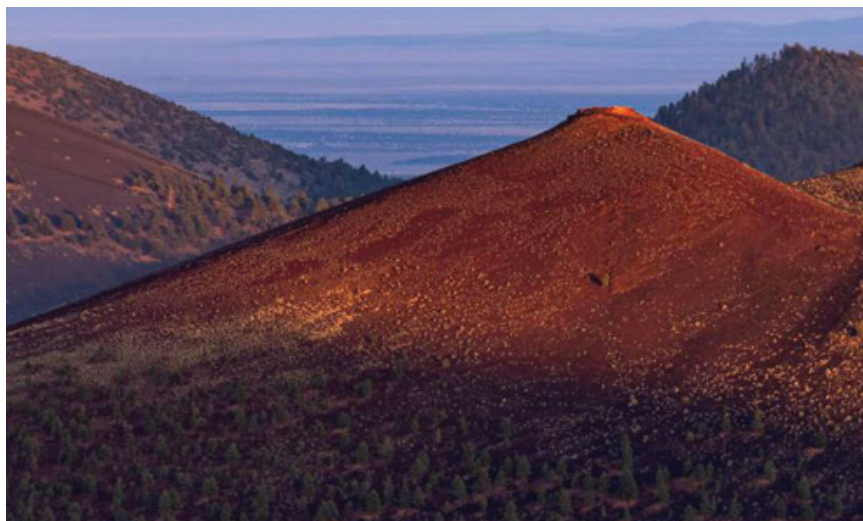
The Hopi today occupy three mesas east of where the Winona meteorite was found and northeast of Meteor Crater. Hopi ancestors left footprints throughout the region in the form of archaeological materials, including petroglyphs, pit houses, pueblos, ceramics, and tools. Among those materials is the Winona meteorite, which was buried in a basaltic stone cist — a stone-lined enclosure — near a vacated pueblo.

The site sits among volcanic cinder cones several hundred feet tall and is surrounded with ash-rich soils. At nearly the same time as the Winona meteorite fell, the Sunset volcanic crater erupted around 10 miles (16 km) away, forcing migrations to places like Winona where the land was suitable for growing corn, squash, and beans.

Pueblo ancestors were stargazers, building the results of their observations into their architecture and recording features in petroglyphs. The Milky Way, which the Hopi call Soongwupa, is particularly prominent. Hopi artist Gerald Dawavendewa wrote in his 2021 book *Codex Taawa: Exploring the Cosmos of the Hopi* that Soongwupa “holds prayer feathers, promises of life with blessings.”

We do not know if the Winona meteorite fell during daylight or at night. But we can infer that Hopi ancestors observed the fall, because they collected and preserved the meteorite.

What might have been the circumstances of that fall? Perhaps two youths tending a cornfield, guarding against threatening pests or repairing windbreaks, were startled by a series of detonations like thunder and confused because the sky was cloudless. As they scanned the sky for an explanation, perhaps they spotted a swirling trail of gray “smoke” before a whistling rock passed by their heads, crashing into their cornfield.





Or maybe a family, sitting outside their pueblo soon after dusk, was startled to see a particularly bright meteor in the sky and heard thunderous noises before the light blinked out. The next morning, on their way to a nearby streambed, they connected those events to the large stone with a glistening black surface lying in their path.

Regardless of the circumstances, the ancestral Hopi collected the specimen and took actions to preserve the sample, burying it in a cist, where it lay preserved for the next 900 years. We do not know — and cannot presume — their reasons.

But we do know that ancestral Hopi also visited the site where the first star fell in this story — Meteor Crater, or Yuvukpu. As Dawavendewa wrote, “even Hoopoq’yaqam [ancient people] did not know how it came to be,” because the formation of Meteor Crater occurred before their arrival. Many years later, however, they built structures on the rim of the crater and surrounding plain.

When the asteroid smashed into the ground, most of it was obliterated upon impact. But spalled-off fragments of unshocked material were strewn about the surrounding plain, and shock-metamorphosed fragments of the asteroid, including some with diamond, were distributed along the crater rim.

Hopi ancestors treated these fragments similarly to the Winona

meteorite. “They found parts of the star, which were different from all other stones,” wrote Dawavendewa. “The sacred stars were taken to a rock-lined cist and placed into the Earth wrapped in a turkey-feather blanket.”

One Meteor Crater meteorite was found in a vacated pueblo a few miles from northern

At nearly the same time as the Winona meteorite fell, the Sunset volcanic crater erupted around 10 miles (16 km) away, forcing migrations to places like Winona where the land was suitable for growing corn, squash, and beans.

Arizona’s Camp Verde. Ancestral Hopi also collected a piece of graphite from Meteor Crater that was shot through with spectacular veins of silver-colored metal, like lightning in a night sky. That specimen was buried in Elden Pueblo (Pasiwvi) at the base of the San Francisco Peaks

(Nuvatukya’ovi), where Flagstaff is located today.

## The story of two stars

That is how material from a primordial planetesimal, melted and segregated in an impact crater within a few million years of solar system formation, separated further in collisions that shaped the asteroid belt, and, lost from each other for perhaps a half-billion years, crossed paths with Earth — one of them 50,000 to 60,000 years ago, and the other within the past millennium. The two stars together, having fallen in nearly the same place, provided an opportunity to reassemble the original planetesimal. That is a magical sequence of events.

Importantly, that magic was brought to light by those who respected and cared for material that fell from space. Whether it was 900 years ago or during the last century, meteoritic samples were curated by ancestors so that oral, illustrated, and written stories of bygone ages could be told, enriching our understanding of the cosmos. If we were to make a wish on those two falling stars, it would be that this type of magic happens more often. ♡

**David A. Kring** studies meteorites and impact cratering processes. He is perhaps best known for the discovery of the dinosaur-killing Chicxulub impact crater and his planetary training programs at Meteor Crater.

Sunset Crater is named for the red, oxidized spatter surrounding its rim, visible in this photo. It erupted around 940 years ago and lies roughly 15 miles (25 km) northeast of modern-day Flagstaff, Arizona.

NATIONAL PARK SERVICE





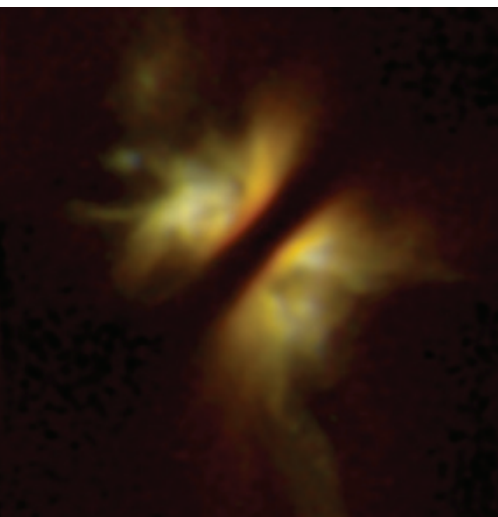
# FROM DUST TO PLANETS

JWST makes the clearest observations yet of an edge-on protoplanetary disk. **BY RICHARD TALCOTT**

ABOVE: A vertical dark band cutting through a bright nebula marks the protoplanetary disk surrounding the young star IRAS 04302+2247. Observations of such disks will help astronomers understand how small dust grains ultimately grow into planets. This photo combines five JWST images with one from Hubble. ESA/WEBB, NASA & CSA, M. VILLENAVE ET AL.

RIGHT: Hubble captured a near-infrared view of this protoplanetary disk a quarter-century ago. The disk's different orientation is simply an artifact of the presentation. D. PADGETT (IPAC/CALTECH), W. BRANDNER (IPAC), K. STAPELFELDT (JPL), AND NASA/ESA





**ASTRONOMERS TYPICALLY** describe the cosmos with numbers that are, well, astronomical. They measure distances within our galaxy in light-years, where 1 light-year equals 5.9 trillion miles (9.5 trillion kilometers), while other galaxies lie millions or even billions of light-years away. And stars typically live billions of years within a universe some 13.7 billion years old.

But these enormous numbers obscure the remarkable pace at which some events transpire. For example, it takes no more than a few million years for micron-sized dust grains to grow into planets thousands of miles across. Scientists don't fully understand how this happens so quickly, though evidence abounds that it has occurred not only in our solar system but also around most of our galaxy's stars.

### **An edge-on view**

A big part of the problem stems from the dust and gas that permeate the protoplanetary disks where the action takes place. This material obscures our view of the process, particularly in visible light. But the infrared-sensitive James Webb Space Telescope (JWST) provides a better perspective as well as superb resolution.

Astrophysicist Marion Villenave at Caltech's Jet Propulsion Laboratory in Pasadena, California, led a team of researchers who used JWST to image the protoplanetary disk that surrounds the young star IRAS 04302+2247. They chose this object because it appears edge-on from our point of view. While a face-on system may reveal rings and gaps that indicate the presence of nascent planets, an edge-on structure shows the disk's thickness, which helps measure the density of dust and the efficiency with which it can form planets.

IRAS 04302+2247 lies about 525 light-years from Earth in L1536, a dark cloud in the Taurus star-forming region. The star itself — hidden by the dust — weighs 1.6 solar masses. It shows the hallmarks of a Class 1 protostar, one at an intermediate stage that appears especially bright at infrared wavelengths but whose gaseous envelope has started to disperse.

The scientists viewed the object with both the Near-InfraRed Camera (NIRCam) and the Mid-InfraRed

**It takes no more than a few million years for micron-sized dust grains to grow into planets thousands of miles across.**

Instrument (MIRI) at five wavelengths ranging from 2.0 to 21 microns. To create the image at left, they added near-infrared observations from Hubble.

The dark vertical slash running through the center of the glowing gas at left marks the protoplanetary disk. The disk's width doesn't change much with wavelength, suggesting that it consists of intermediate-sized grains some 10 microns in diameter. It extends about 40 billion miles (65 billion km), more than five times the diameter of Neptune's orbit around the Sun. On each side of the disk lies a reflection nebula consisting of dust grains that reflect light from the central protostar.

### **A changing perspective**

Intriguingly, the research team notes that the intensity of the two nebulae changes with wavelength. At shorter infrared wavelengths, the eastern side (at right) glows brighter, but the western section wins out at 21 microns. The scientists think the discrepancy arises because the disk's inner region tilts slightly relative to the rest of the structure.

The astronomers also compared the JWST images to those Hubble took some 25 years earlier and found one feature that had moved about 16 astronomical units between the two eras. (One astronomical unit, or AU, is the average Earth-Sun distance of 93 million miles [150 million km].) They suspect this represents a dust knot that has been moving away from the protostar at some 6,700 mph (10,800 km/h). »

---

*Contributing Editor* **Richard Talcott** wrote about JWST's observations of the prolific Sagittarius B2 star-forming region in January.

# SKY THIS MONTH

Visible to the naked eye  
Visible with binoculars  
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.

BY MARTIN RATCLIFFE AND ALISTER LING



This month brings a total lunar eclipse, which will darken the sky and turn the Moon a deep orange-red the morning of March 3.

STEPHEN RAHN

as the Moon sets in the west. From the Central time zone, the Moon stands about 20° high in the western sky during totality. Observers in the Mountain and Pacific time zones see the total eclipse in a dark sky. After totality in the Mountain time zone, the Moon passes through the partial phases as twilight grows. The partial phase ends at 6:18 A.M. MST.

**Venus** appears in the evening sky shining at magnitude -3.9, an easy target to spot soon after sunset. On March 7 and 8 it lies close to **Saturn**, which is a much fainter magnitude 1.0. Use Venus as a guide: Check for the close pairing 30 minutes after sunset, when Venus is 7° high. Grab binoculars — Saturn

## Early-morning lunar eclipse

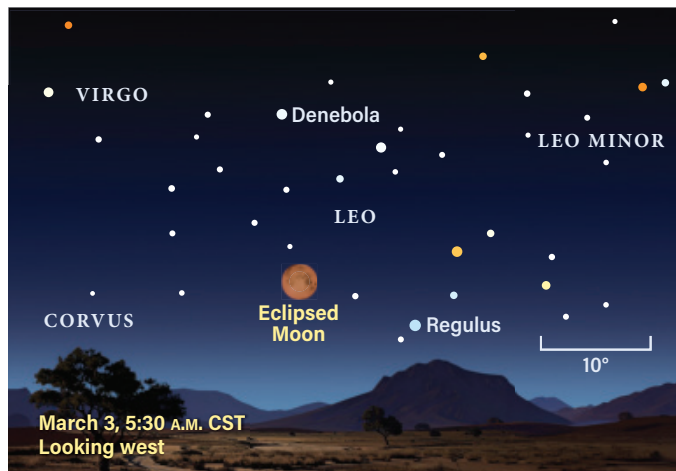
» A total lunar eclipse is the highlight of the month. For planetary action, Jupiter is well placed most of the night and there are many events involving its Galilean moons. Soon after sunset, brilliant Venus appears low in the western sky. Within reach of binoculars, Uranus wanders close to stars that are easy to find south of the Seven Sisters. It's a great time to spot this distant globe.

A total lunar eclipse is visible across the U.S., Canada, Mexico, and parts of South America the morning of March 3. It is also observable after sunset in Australia, New Zealand, Asia, and Indonesia.

Watch the Moon rise on March 2 among the stars of Leo. Stay up past midnight into the early hours of March 3 to see the subtle penumbral shadow fall across the Moon, beginning at 3:43 A.M. EST. The partial phase begins at 4:50 A.M. EST. During the next hour, the sky darkens as the Moon moves deeper into Earth's shadow and takes on an orange hue as totality approaches. The sky is filled with stars at the onset of totality at 6:04 A.M. EST, which lasts for 59 minutes as the Moon crosses the southern part of Earth's shadow.

The Eastern time zone sees totality during morning twilight

Eclipsed Moon setting



By mideclipse the morning of March 3, the Moon is some 10° high and sinking toward the horizon in the Midwest; it is higher for observers farther west.

ALL ILLUSTRATIONS: ASTRONOMY: ROEN KELLY



## OBSERVING HIGHLIGHT

**A TOTAL LUNAR ECLIPSE** occurs March 3, with totality beginning at 6:04 A.M. EST.



will pop into view easily. If you swing a telescope toward Venus, you'll see a 97-percent-lit disk spanning 10". Venus and Saturn set 70 minutes after the Sun.

**Neptune** is a little more than 1° northwest of Saturn; it is not easy to see it in twilight at this low altitude. Neptune reaches conjunction with the Sun March 22. Saturn reaches solar conjunction three days later.

Venus continues to climb higher as it extends its elongation from the Sun. A slender crescent Moon joins the region March 19 and 20. On the 19th, it's a challenge to find the one-day-old Moon some 6° to the lower right of Venus. Catch it within 45 minutes of sunset, before the Moon descends too low. On the 20th, the Moon stands 9° above Venus and is much easier to see.

**Uranus** is visible just south of the Pleiades (M45) all evening. It's a perfect month to spot the planet, due to its proximity to an easy-to-find pair of stars shining with similar brilliance. Uranus sets soon after midnight. At magnitude 5.8, it generally requires binoculars or a telescope to view, although it is technically within range of the unaided eye.

There's a pair of stars 4.5° south of M45 called 13 and 14 Tauri. They shine at magnitude 5.7 and 6.1, respectively. As March begins, Uranus stands 0.5° southwest of brighter

— Continued on page 34

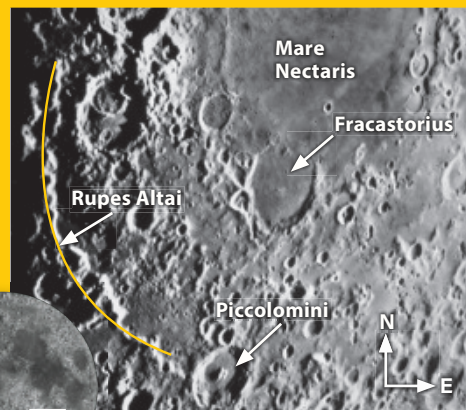
## RIISING MOON | Fabulous Fracastorius

**THERE'S MUCH MORE** to lunar history than newer craters erasing older features. The massive impact that carved out Mare Nectaris affected the face of cratering history for millions of years to come. Lying just south of the equator, the Sea of Nectars is fully illuminated on the 23rd. Immediately catching the eye on its west side is a trio of fantastic craters and a bright white arc of a quarter circle, the Altai Scarp (also called Rupes Altai). Perfectly centered on Nectaris, the arc is one of the remains of the fourth rim of a multi-ring basin. Can you detect the others?

The younger crater Piccolomini dangles on the end of the Altai Scarp like an earring. Spanning some 55 miles, it is large enough that it sports a complex of central peaks instead of the single one seen in the many smaller pockmarks that pepper the surroundings. Check out its walls: Like a hole dug in wet sand at the beach, a lot of material slumps into the cavity. But the south side has much more, thanks to the unstable terrain first generated by the formation of the scarp.

Intermediate in age is the broken circle of Fracastorius. Lava, like water, runs toward level ground, making it obvious that Fracastorius is tilted down to the northeast. Lunar geologists have deduced that before this last flood, a smaller but earlier surge of lava rose up through cracks in Nectaris' floor, then solidified and sunk the central part, causing the surrounding terrain

### Fracastorius and Piccolomini



Piccolomini marks one end of Rupes Altai, the curved scarp running from upper to lower left in this photo. CONSOLIDATED

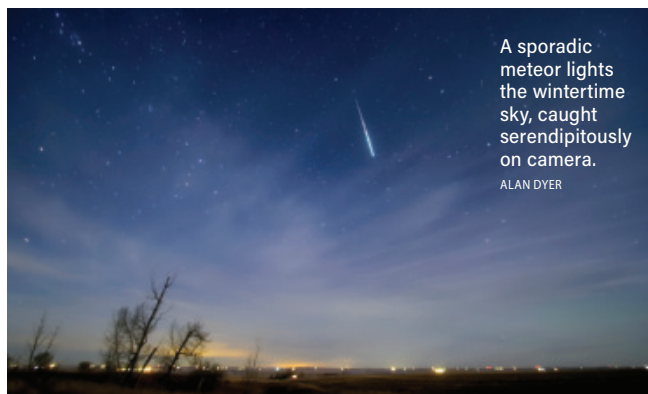
LUNAR ATLAS/UA/LPL. INSET: NASA/GSFC/ASU

to tilt down toward the middle. Fracastorius was not given that name because it is fractured, but to honor 16th-century Italian astronomer Girolamo Fracastoro.

If you miss this occasion, similar illumination returns to the region April 21st. That's when you can watch the peaks of the Altai Scarp and Piccolomini pop into view one by one as the evening progresses. With the Sun slowly rising over the lunar terrain, high points to the west and lower points to the east light up with each passing half-hour.

## METEOR WATCH | Chase fainter lights

### Unplanned delight



A sporadic meteor lights the wintertime sky, caught serendipitously on camera.

ALAN DYER

**FOR THE SECOND MONTH** in a row, no major meteor showers occur. The background or sporadic rate generates about half a dozen meteors an hour on a moonless night with dark skies.

Mid-March, around the time of New Moon, is a good time to look for them.

It's also the second month in a row for attempting to view the zodiacal light in the evening sky.

The zodiacal light is aligned with the ecliptic, Earth's orbital plane, and passes through the constellations Pisces, Aries, and Taurus. Any time after March 8, when the waning Moon rises after 11 P.M. local daylight time, is a good time to try.

The zodiacal light comes from sunlight reflecting off the fine dusty debris littering the plane of the ecliptic, left by ancient comets. Once the low arcing glow of twilight has gone, look for a delicate cone-shaped glow extending high above the western horizon. You'll need a very dark moonless sky with no interfering streetlights to your west. Try using peripheral vision to spot the cone of light by scanning left to right along the horizon. It's remarkable when you see it.

# STAR DOME

## HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. March 1

10 P.M. March 15

9 P.M. March 31

Planets are shown at midmonth

## MAP SYMBOLS

- Open cluster
- ⊕ Globular cluster
- Diffuse nebula
- ⊛ Planetary nebula
- Galaxy

## STAR MAGNITUDES

- Sirius
- 0.0    ● 3.0
- 1.0    ● 4.0
- 2.0    ● 5.0

## STAR COLORS

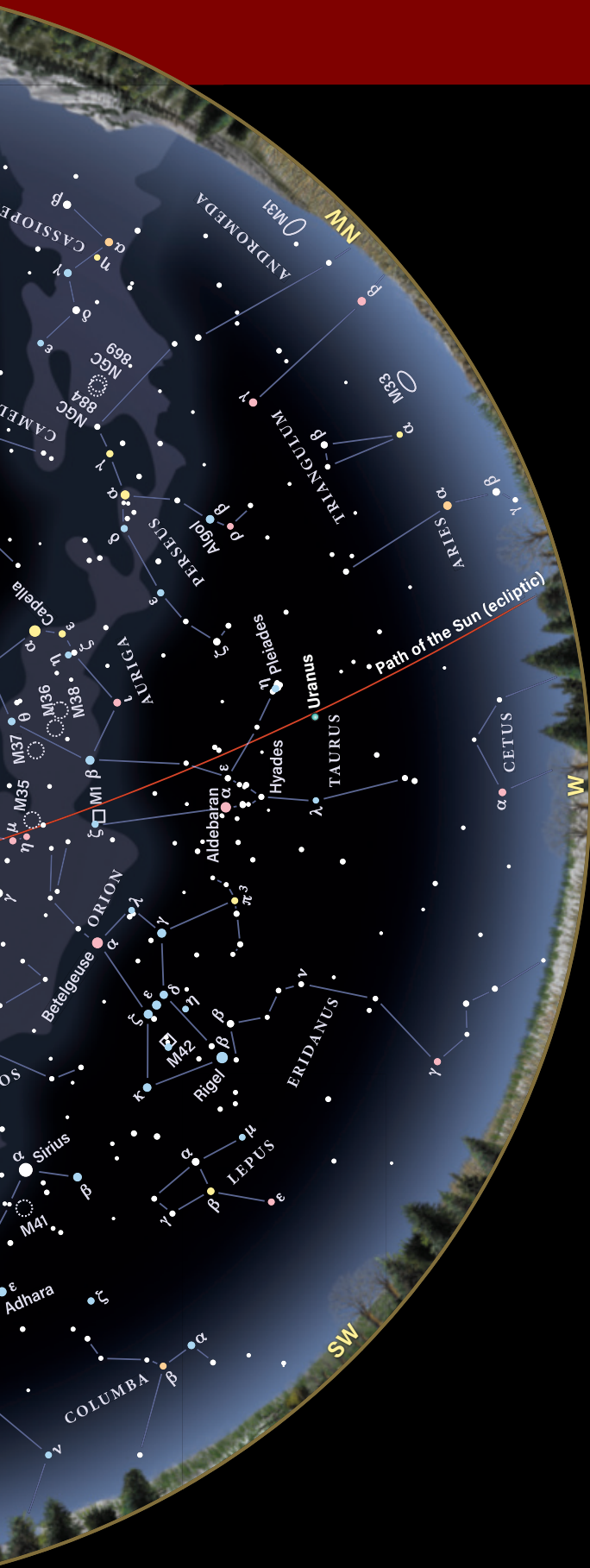
A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light



BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT [www.Astronomy.com/starchart](http://www.Astronomy.com/starchart).





# MARCH 2026

| SUN.                                                                                 | MON.                                                                                 | TUES.                                                                                  | WED.                                                                                   | THURS.                                                                                 | FRI.                                                                                   | SAT.                                                                                   |
|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
|  1  |  2  |  3  |  4  |  5  |  6  |  7  |
|  8  |  9  |  10 |  11 |  12 |  13 |  14 |
|  15 |  16 |  17 |  18 |  19 |  20 |  21 |
|  22 |  23 |  24 |  25 |  26 |  27 |  28 |
|  29 |  30 |  31 |                                                                                        |                                                                                        |                                                                                        |                                                                                        |

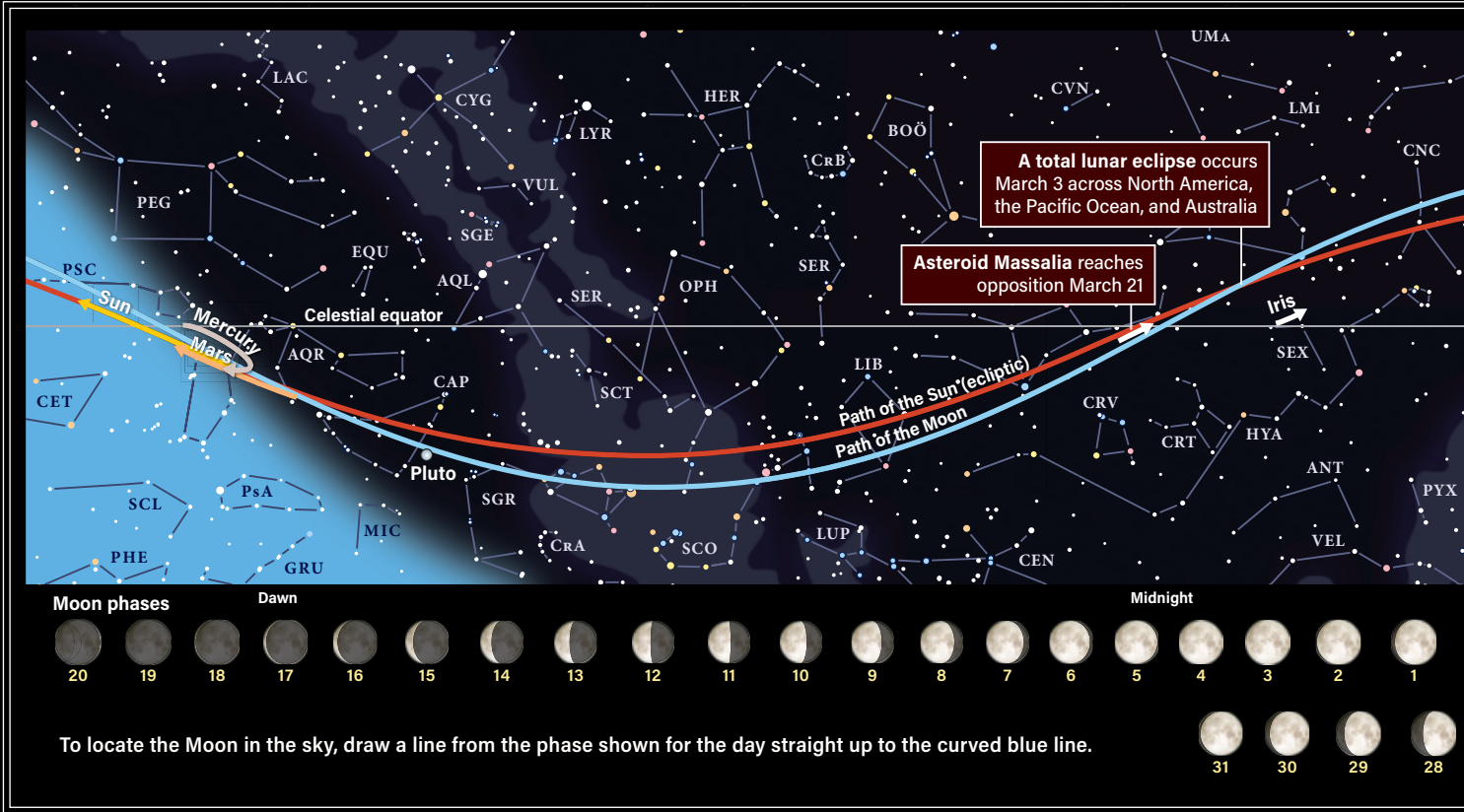
ILLUSTRATIONS BY ASTRONOMY ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

## CALENDAR OF EVENTS

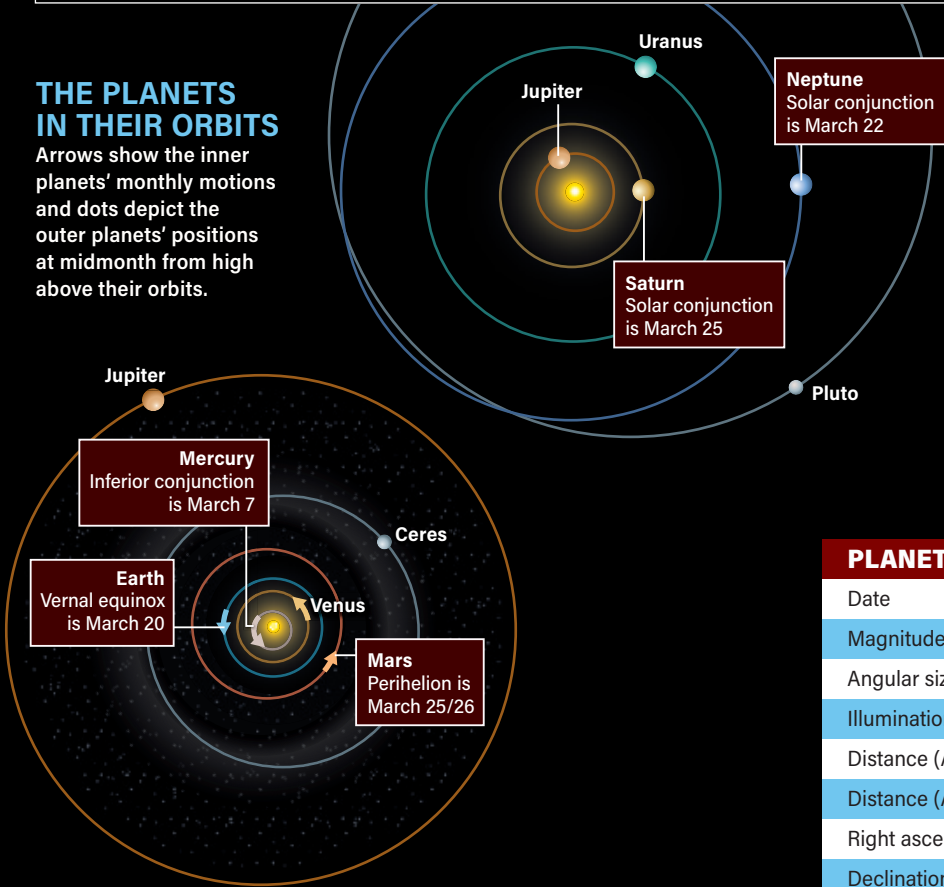
- 2 The Moon passes 0.4° north of Regulus, 8 A.M. EST  
Asteroid Pallas is in conjunction with the Sun, 10 A.M. EST
- 3  Full Moon occurs at 6:38 A.M. EST; total lunar eclipse
- 7 Mercury is in inferior conjunction, 6 A.M. EST
- 10 The Moon passes 0.7° south of Antares, 8 A.M. EDT  
The Moon is at apogee (251,273 miles from Earth), 9:43 A.M. EDT  
Jupiter is stationary, 11 P.M. EDT
- 11  Last Quarter Moon occurs at 5:39 A.M. EDT
- 14 The Moon passes 1.0° north of Pluto, 9 P.M. EDT
- 17 The Moon passes 2° south of Mercury, 10 A.M. EDT  
The Moon passes 1.5° north of Mars, 6 P.M. EDT
- 18  New Moon occurs at 9:23 P.M. EDT
- 19 Mercury is stationary, 4 P.M. EDT
- 20 The Moon passes 5° north of Venus, 9 A.M. EDT  
Vernal equinox occurs at 10:46 A.M. EDT
- 21 Asteroid Massalia is at opposition, 11 A.M. EDT
- 22 Neptune is in conjunction with the Sun, 7 A.M. EDT  
The Moon is at perigee (227,954 miles from Earth), 7:40 A.M. EDT
- 23 The Moon passes 5° north of Uranus, 4 A.M. EDT
- 25 Saturn is in conjunction with the Sun, 5 A.M. EDT  
 First Quarter Moon occurs at 3:18 P.M. EDT
- 26 Mars is at perihelion (128 million miles from the Sun), 3 A.M. EDT  
The Moon passes 4° north of Jupiter, 8 A.M. EDT
- 29 The Moon passes 0.3° north of Regulus, 4 P.M. EDT

# PATHS OF THE PLANETS



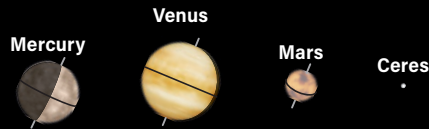
## THE PLANETS IN THEIR ORBITS

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.



## THE PLANETS IN THE SKY

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.



| PLANETS                  | MERCURY  | VENUS    |
|--------------------------|----------|----------|
| Date                     | March 31 | March 15 |
| Magnitude                | 0.4      | -3.9     |
| Angular size             | 8.1"     | 10.3"    |
| Illumination             | 44%      | 96%      |
| Distance (AU) from Earth | 0.827    | 1.623    |
| Distance (AU) from Sun   | 0.464    | 0.724    |
| Right ascension (2000.0) | 22h57.3m | 0h39.4m  |
| Declination (2000.0)     | -7°55'   | 3°06'    |



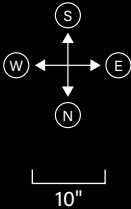
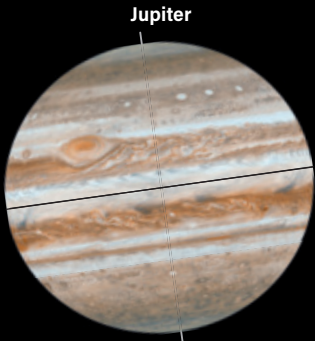
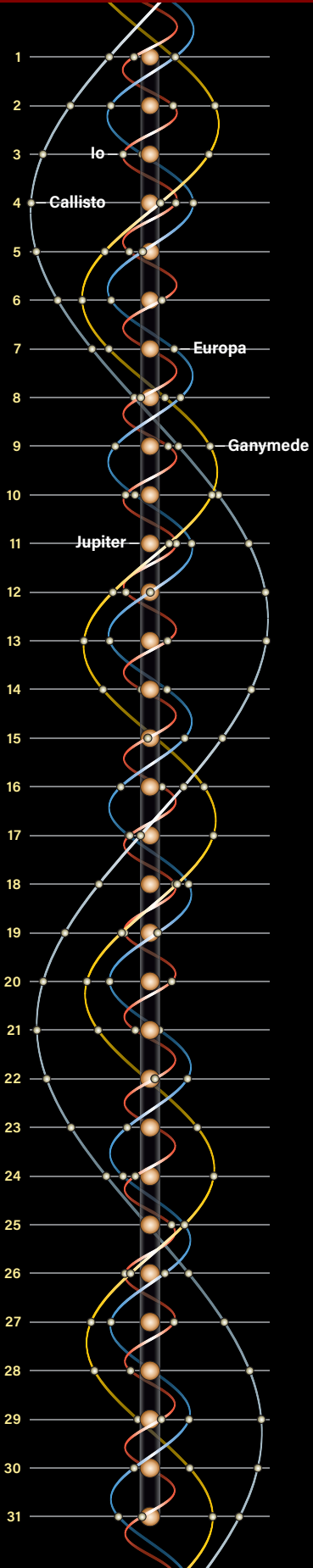
This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

# MARCH 2026



## JUPITER'S MOONS

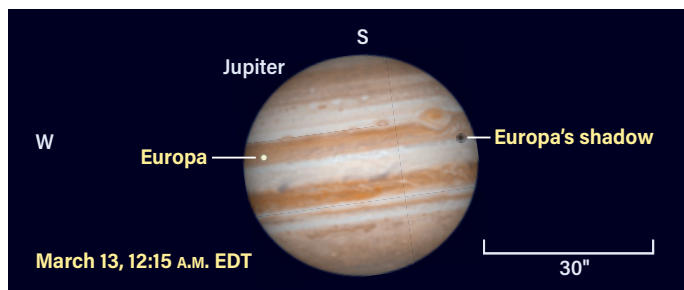
Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.



| MARS     | CERES    | JUPITER  | SATURN  | URANUS   | NEPTUNE  | PLUTO    |
|----------|----------|----------|---------|----------|----------|----------|
| March 31 | March 15 | March 15 | March 1 | March 15 | March 15 | March 15 |
| 1.2      | 9.1      | -2.3     | 1.0     | 5.8      | 7.8      | 15.3     |
| 4.1"     | 0.4"     | 41.0"    | 16.0"   | 3.5"     | 2.2"     | 0.1"     |
| 99%      | 99%      | 99%      | 100%    | 100%     | 100%     | 100%     |
| 2.297    | 3.580    | 4.804    | 10.416  | 19.897   | 30.869   | 36.108   |
| 1.381    | 2.835    | 5.238    | 9.500   | 19.477   | 29.883   | 35.472   |
| 23h32.2m | 1h57.4m  | 7h04.2m  | 0h08.4m | 3h42.1m  | 0h06.5m  | 20h31.5m |
| -4°09'   | 6°22'    | 22°59'   | -1°25'  | 19°29'   | -0°43'   | -22°55'  |

# SKY THIS MONTH — Continued from page 29

## Briefly together 🔭



Catch Europa and its shadow on Jupiter's disk at the same time for a brief period as the moon transits. Note that while this view occurs early on March 13 in the Eastern time zone, it is still late on March 12 farther west.

13 Tau. If you can see this star with the unaided eye, you might also spot Uranus. Uranus' motion carries it due south of 13 Tau by the 15th, when the planet stands 12' south of this star. On the 25th, Uranus is 5' south of 14 Tau. By the 31st, Uranus has moved to sit 14' east-southeast of 14 Tau. Through a telescope, the tiny disk of Uranus spans 4" and appears distinctly nonstarlike. It possess a subtle bluish-green hue.

**Jupiter** dominates the evening sky in the constellation Gemini. It begins March at magnitude -2.4 and fades only 0.2 magnitude by the end of the month. It's highest in the south around 8:30 P.M. local time on March 1, and by 7:30 P.M. local daylight time on March 31. Usually there is a two-hour difference in transit time by the end of the month, but daylight saving time begins March 8. Jupiter sets by 3 A.M. local daylight time on the 31st, offering many hours of observability.

Jupiter's motion across Gemini is westerly at first, then halts March 10 and resumes toward the east. The planet forms a triangle with 4th-magnitude Wasat and Mekbuda (Delta [δ] and Zeta [ζ] Geminorum, respectively). A waxing Moon joins Jupiter in Gemini March 25th and 26th, drawing attention.

Jupiter displays a 43"-wide disk March 1, which shrinks to 39" by the end of the month, owing to the planet's slowly increasing distance from Earth. Through a telescope, Jupiter offers a lot to look at. Two dark belts straddle the equator, and more subtle banding is evident if you wait patiently for calm moments of seeing — the key to success with viewing detail on

any planet. Look also for the Great Red Spot, a dark oval storm on the edge of the South Equatorial Belt. It's not always visible, but with Jupiter's speedy rotation rate of less than 10 hours, it often wanders into view. You can follow it and other features across the disk in just a short period of time.

Io, Europa, Ganymede, and Callisto orbit Jupiter every two to 17 days, and occasionally pass in front of the planet in a transit or become hidden behind it in an occultation.

March opens with Jupiter's largest moon, Ganymede, transiting the disk March 4/5. The event begins at 12:33 A.M. EST (the 5th in Eastern time only, late on the 4th for all other U.S. time zones). It takes a few minutes for the moon to appear fully in front of the disk. Ganymede takes over three hours to transit, leaving at

## WHEN TO VIEW THE PLANETS

### EVENING SKY

Venus (west)  
Jupiter (south)  
Saturn (west)  
Uranus (west)  
Neptune (west)

### MIDNIGHT

Jupiter (west)  
Uranus (west)

### MORNING SKY

Mercury (east)

2:48 A.M. CST, about the time Jupiter sets in the Midwest.

Io orbits in a little less than two days. A transit overnight on March 6/7 begins at midnight EST on the 6th. As Io approaches the middle of the disk an hour later, watch the eastern limb for Io's shadow, which appears at 1:05 A.M. EST (now the 7th for the eastern half of the U.S.). The evening of the

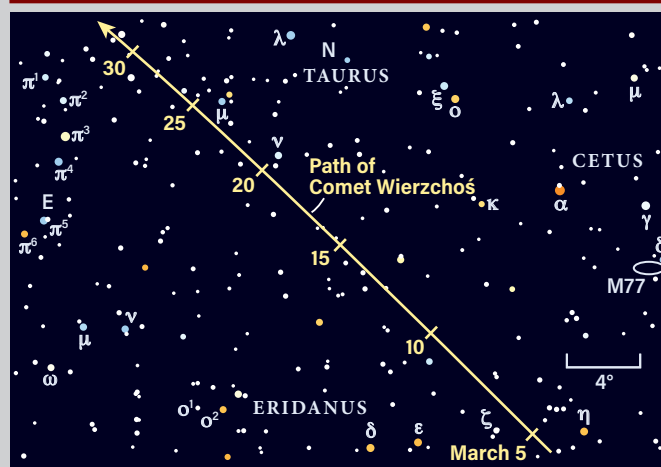
## COMET SEARCH | Non-stellar marathon

**SPRINGING UPWARD** from the southwestern horizon, C/2024 E1 (Wieruchoś) offers a long farewell after a nice showing in the Southern Hemisphere. Under a dark sky, the 8th-magnitude puffball is visible in binoculars as it leaves the shores of Eridanus for Taurus. The moonless window opens on the 5th.

Many observers will be at the eyepiece all night midmonth for the annual Messier marathon. Compare this classic comet to the Crab Nebula (M1), the bright Seyfert spiral M77, and the round globular M79. Wieruchoś' asymmetric shape should stand out: a sharply-defined northern flank and a soft, fading southern one. During the two weeks of darkness, watch it fade to 10th magnitude as it retreats to the distant Oort Cloud.

By 1 A.M. you've conquered the Virgo Cluster and are primed to pick up 10th-magnitude Comet 24P/Schaumasse in Serpens. Start with 10th-magnitude globular NGC 5634 — the two might be fraternal twins. Then bump up the power to hone in on Schaumasse and the background galaxy NGC 5921. Which is brighter?

### Comet C/2024 E1 (Wieruchoś) 🔭



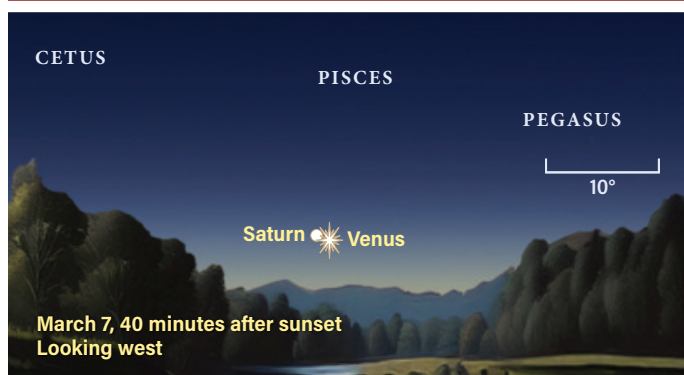
Comet Wieruchoś is moving quickly but can be found with binoculars early in the month. This chart shows the comet's path starting March 5, when moonless viewing begins.



## LOCATING ASTEROIDS |

### Early blossom

Look over here   



After sunset on the 7th, use bright Venus to guide you to fainter Saturn. If you can't see the ringed planet by eye, try using binoculars.

7th then finds Io approaching the western limb of Jupiter — it disappears behind the giant disk about 9:20 P.M. EST. You might think you can watch it reappear two hours later, but Jupiter's extended shadow hides the moon as Io is eclipsed. Io finally emerges from the shadow at 12:43 A.M. EST (now the 8th in the Eastern time zone), about 20" east of Jupiter's limb.

This sequence repeats March 13/14. A transit of Io begins at 2:52 A.M. EDT on the 14th (note the change to DST), followed by its shadow at 2:00 A.M. MDT. The latter isn't visible from the Eastern time zone, and Jupiter is very low for Midwest observers. The night of March 14/15, Io is occulted by Jupiter around 12:10 A.M. EDT on the 15th (in the Eastern time zone only).

Europa transits Jupiter March 12/13, 19/20, and 26/27. On the 12th, the transit begins about 9:40 P.M. EDT and is underway as darkness falls across the Mountain time zone. Since Europa has a larger orbit than Io, it takes longer for its shadow to appear when compared to Io's — Europa's shadow moves onto the disk at midnight

EDT. The next transit begins at 12:12 A.M. EDT on the 20th (in Eastern time only), with the next transit starting on the 27th at 2:44 A.M. EDT (still the 26th for the West Coast). In both later events, the shadow transit occurs just under 2.5 hours later, which you can observe if Jupiter is still visible.

Callisto is occulted by Jupiter March 9 about 3:30 A.M. MDT (only visible from the Mountain and Pacific time zones). Callisto's shadow transits March 18, with Callisto more than 1' west of the planet. Watch for the extended shadow to begin appearing around 2:05 A.M. CDT, with Jupiter very low for locations along the East Coast. Within five minutes, the shadow becomes an evident dark bite out of Jupiter's southeastern limb. It takes about two hours to reach the center of the planet's disk.

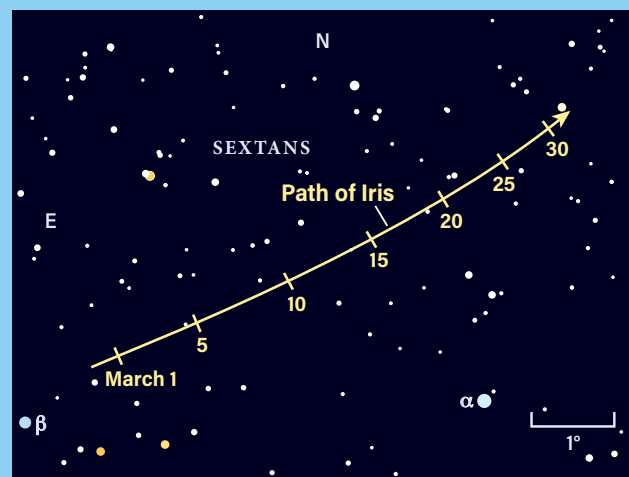
Finally, watch Callisto reappear from occultation at Jupiter's northeastern limb around 1:30 A.M. CDT on March 26, with Jupiter quite low for observers in the Eastern time zone. Callisto is far enough from Jupiter that it is not eclipsed by the planet's shadow.

**INSTEAD OF** rushing to sight the retreating main-belt ruler 1 Ceres, turn east for the brighter flower of the night: 7 Iris. With blue-white luminary Regulus lighting the way, drop south a few degrees to Alpha ( $\alpha$ ) and Beta ( $\beta$ ) Sextantis. Celestial savannah or sea, this area of the sky is far from the Milky Way, clearing the way for the 9th-magnitude asteroid to outshine most background stars.

A 3- to 4-inch scope from the suburbs can handle this dot; if you have an 8-inch SCT with a go-to mount, it will reveal Iris in 200 seconds or less. That said, waiting to see motion can be the fun part of asteroid observing. In the first week of March, Iris traces the north side of a zigzag of 9th-magnitude dots that serve to anchor a sketch of its nightly displacement. On the 14th and 19th, Iris is the slightly brighter of a wide cat's-eyes pair, doubling the separation over a three-hour session. An unequal doublet guideposts the drift for March 20–22. On the 21st, you ought to see the change in angles in under three hours.

Fourth brightest of the main-belt asteroids, Iris was picked up by John Russell Hind in 1847, at the beginning of the second wave of minor planet discoveries that ended a nearly 40-year drought since the first four.

Use the Sextant  



Iris traces a path through Sextans this month, sticking near the constellation's two brightest stars.

**Mercury** reappears in the morning sky after its conjunction with the Sun March 7. On March 22, Mercury rises about an hour before the Sun and reaches magnitude 0.9. Look for it low in the eastern sky as dawn breaks. It stands nearly 5° high at 6:30 A.M. local daylight time. By March 31, it reaches magnitude 0.4 but is dipping south of the ecliptic, so its elevation doesn't increase much and it is still about 5° high 30 minutes before sunrise.

**Mars** remains close to the Sun and isn't visible this month.

The vernal equinox, when the Sun is on the celestial equator and moving north, occurs March 20 at 10:46 A.M. EST. ☞

**Martin Ratcliffe** is a *planetarium professional with Evans & Sutherland and enjoys observing from Salt Lake City. Alister Ling, who lives in Edmonton, Alberta, is a longtime watcher of the skies.*



GET DAILY UPDATES ON YOUR NIGHT SKY AT  
[www.Astronomy.com/skythisweek](http://www.Astronomy.com/skythisweek).



# RUN THE MESSIER MARATHON

All you need to complete this classic list is a good telescope, a clear sky, and energy. **TEXT**

**AND IMAGES**

**BY MOLLY  
WAKELING**

**FRENCH ASTRONOMER**  
Charles Messier did not intend to be remembered for his discoveries of galaxies, nebulae, and stars clusters when he looked to the sky in the 1750s. Dubbed the “Ferret of Comets” by French King Louis XV after Messier’s acceptance into the French Academy of Sciences in 1770, he discovered 13 comets and

observed many more, expecting to be remembered for his comet work.

One night while searching the sky to recover Halley’s Comet on its predicted return in 1758, he came across a fuzzy patch of light in Taurus. He determined through subsequent observations that it was stationary, and thus not a comet. He recorded its

position so as not to mistake it for a comet in the future. Messier 1 (M1) — later known as the Crab Nebula — thus began his list of “nuisance” objects to be avoided while comet hunting.

## **Messier’s catalog**

Messier published the first edition of his catalog for other comet-hunters in the *Journal*



of the French Academy of Sciences in 1774. It contained 45 objects, 17 of which were discovered by Messier and the remaining by others. By 1780, the total number reached 80, and finally 103 when it was published in the annual *Connaissance des temps* (*Knowledge of the Times*) in 1781. He primarily observed all of these with a 100mm (4-inch) refractor from the Hôtel de Cluny (now the Musée national du Moyen Âge) in downtown Paris, which of course had darker skies in the 18th century. After 1921, six more objects were added by astronomers who scoured Messier's notes, rounding out the Messier catalog at 109 deep-sky objects.

Today, Messier's catalog is a great place for beginning astronomers to learn the art of observing because it contains some of the brightest and most beautiful objects in the sky. Most of these are also visible through modest telescopes, and many are discernible through binoculars.

One important fact about the Messier objects is that they're not evenly distributed across the sky. There is a lack of objects between right ascensions 21h40m to 23h20m; therefore, it is possible, from some northern latitudes, to observe all 109 objects in a single night for a few-week period between mid-March and early April. Although ideal from 25° north, it is possible to catch the whole catalog between about 3° and 42° north. For 2026, the best weekend night is March 21, which is nearest to the New Moon on March 18.

The Messier marathon was created by several amateur astronomers around the same time in the 1970s, including Tom Hoffelder, Tom Reiland, and Don Machholz. Now

many astronomy clubs hold annual events for those who are willing to stay up all night. Are you ready to take the challenge?

## Running the marathon

To have the best chance of success, some preparations are necessary. Scout a site that has a good eastern and western horizon. Arrive early so you're ready to roll during astronomical twilight. You'll need to hunt for some of the targets before it's fully dark.

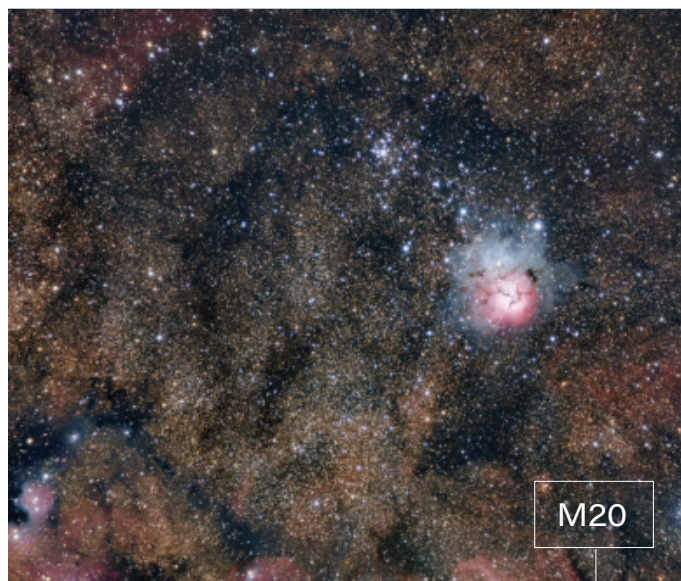
Make a plan. You'll need to observe several of the targets quickly, so know where to

then you can slow your pace. But not too much. Use that energy so you have some extra time to tackle the dense Virgo Cluster later. I recommend taking a 15- to 30-minute break before visiting these galaxies. Have a snack, rest your feet, and prepare for the next sprint.

After winding through the Virgo Cluster, continue down the list at a more leisurely pace until you hit the horizon. Then you can take another break until the Milky Way is higher in the sky. You even have a couple hours to take a nap. But be sure to set an alarm!

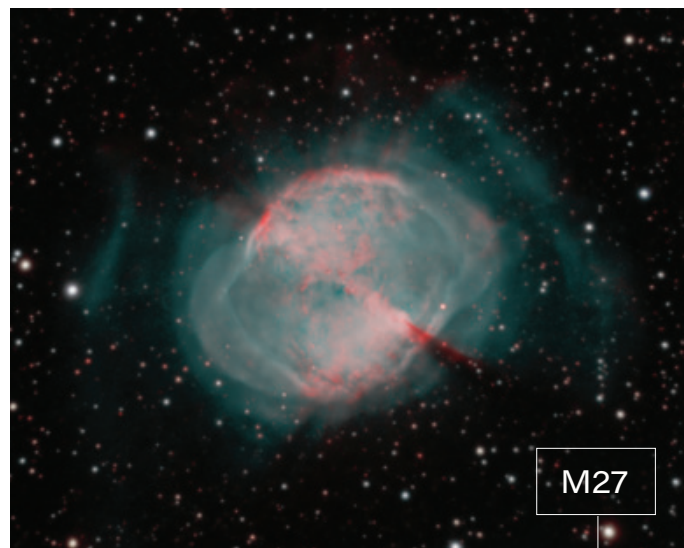
## WHAT ABOUT M102?

You may have heard about the controversy over M102. In 1781, Messier's friend and assistant Pierre Méchain discovered it but later believed that M102 had been a reobservation of M101, so he retracted it from the published list. However, there is historical evidence that the Spindle Galaxy (NGC 5866) is what he observed. For what it's worth, the Hubble Space Telescope's Messier catalog images include the Spindle Galaxy as M102. —M.W.



point your scope next by having a checklist. You'll want at least a 4-inch telescope, but the bigger, the better. And don't forget important support equipment, such as dew zappers, Telrads, red lights, chairs, tables, and extra batteries.

To catch the first objects before they set, you may need to search in twilight, depending on your latitude. The galaxies M77 and M74 in particular will be difficult. View the first 10 quickly, and



In the wee hours, enjoy the 15 objects in Sagittarius, including the Lagoon Nebula (M8) and the Trifid Nebula (M20). A nebula filter is nice, but you're not doing detailed observing. Check them off your list and keep going.

Gather your energy for the last stretch: You must catch the faint globular cluster M72,

dim four-star asterism M73, and the just-rising globular cluster M30 as the Sun threatens to hide them. You may want to do a dry run before the night of the marathon on the twilight objects and the winding path through the Virgo Cluster to have the best chance of success on the actual night.

The most important part of a Messier marathon is to have fun. Even if you don't sweep up all 109 objects, you'll have improved your observing skills, and you'll have a night to remember.

## An imaging marathon?

With the ever-growing

popularity of astroimaging, a photographic Messier marathon is possible. I attempted one in 2021, where 100 of the objects were visible from my San Francisco-area backyard. I managed to catch 66, but it took me a week and two telescopes to do it. Now that I'm more experienced, I plan on attempting it again this year.

## TARGET THE MESSIER OBJECTS IN THIS ORDER

Your ideal order will differ with latitude, but this is a good place to start. Be sure to set up well before dark, and try to log the first few objects while there's still some light in the sky.

| Messier number | Constellation  | Type | Magnitude |
|----------------|----------------|------|-----------|
| M77            | Cetus          | Gal  | 8.9       |
| M74            | Pisces         | Gal  | 9.4       |
| M33            | Triangulum     | Gal  | 5.7       |
| M31            | Andromeda      | Gal  | 3.4       |
| M32            | Andromeda      | Gal  | 8.2       |
| M52            | Cassiopeia     | OC   | 6.9       |
| M103           | Cassiopeia     | OC   | 7.4       |
| M76            | Perseus        | PN   | 10.1      |
| M34            | Perseus        | OC   | 5.2       |
| M45            | Taurus         | OC   | 1.5       |
| M79            | Lepus          | GC   | 7.7       |
| M42            | Orion          | Neb  | 3.7       |
| M43            | Orion          | Neb  | 9.0       |
| M78            | Orion          | Neb  | 8.0       |
| M1             | Taurus         | SNR  | 8.0       |
| M35            | Gemini         | OC   | 5.1       |
| M37            | Auriga         | OC   | 5.6       |
| M36            | Auriga         | OC   | 6.0       |
| M38            | Auriga         | OC   | 6.4       |
| M41            | Canis Major    | OC   | 4.5       |
| M93            | Puppis         | OC   | 6.2       |
| M47            | Puppis         | OC   | 4.4       |
| M46            | Puppis         | OC   | 6.1       |
| M50            | Monoceros      | OC   | 5.9       |
| M48            | Hydra          | OC   | 5.8       |
| M44            | Cancer         | OC   | 3.1       |
| M67            | Cancer         | OC   | 6.0       |
| M95            | Leo            | Gal  | 9.7       |
| M96            | Leo            | Gal  | 9.2       |
| M105           | Leo            | Gal  | 9.3       |
| M65            | Leo            | Gal  | 9.3       |
| M66            | Leo            | Gal  | 8.9       |
| M81            | Ursa Major     | Gal  | 6.9       |
| M82            | Ursa Major     | Gal  | 8.4       |
| M97            | Ursa Major     | PN   | 9.9       |
| M108           | Ursa Major     | Gal  | 10.0      |
| M109           | Ursa Major     | Gal  | 9.8       |
| M40            | Ursa Major     | DS   | 9.6/10.0  |
| M106           | Canes Venatici | Gal  | 8.4       |

| Messier number | Constellation  | Type | Magnitude |
|----------------|----------------|------|-----------|
| M94            | Canes Venatici | Gal  | 8.2       |
| M63            | Canes Venatici | Gal  | 8.6       |
| M51            | Canes Venatici | Gal  | 8.4       |
| M101           | Ursa Major     | Gal  | 7.9       |
| M102           | Draco          | Gal  | 9.9       |
| M53            | Coma Berenices | GC   | 7.7       |
| M64            | Coma Berenices | Gal  | 8.5       |
| M3             | Canes Venatici | GC   | 6.0       |
| M98            | Coma Berenices | Gal  | 10.1      |
| M99            | Coma Berenices | Gal  | 9.9       |
| M100           | Coma Berenices | Gal  | 9.4       |
| M85            | Coma Berenices | Gal  | 9.1       |
| M84            | Virgo          | Gal  | 9.1       |
| M86            | Virgo          | Gal  | 8.9       |
| M87            | Virgo          | Gal  | 8.6       |
| M89            | Virgo          | Gal  | 9.8       |
| M90            | Virgo          | Gal  | 9.5       |
| M88            | Coma Berenices | Gal  | 9.6       |
| M91            | Coma Berenices | Gal  | 10.2      |
| M58            | Virgo          | Gal  | 9.7       |
| M59            | Virgo          | Gal  | 9.6       |
| M60            | Virgo          | Gal  | 8.8       |
| M49            | Virgo          | Gal  | 8.4       |
| M61            | Virgo          | Gal  | 9.7       |
| M104           | Virgo          | Gal  | 8.0       |
| M68            | Hydra          | GC   | 8.0       |
| M83            | Hydra          | Gal  | 7.5       |
| M5             | Serpens        | GC   | 5.7       |
| M13            | Hercules       | GC   | 5.8       |
| M92            | Hercules       | GC   | 6.5       |
| M57            | Lyra           | PN   | 8.8       |
| M56            | Lyra           | GC   | 8.3       |
| M29            | Cygnus         | OC   | 6.6       |

| Messier number | Constellation | Type | Magnitude |
|----------------|---------------|------|-----------|
| M39            | Cygnus        | OC   | 4.6       |
| M27            | Vulpecula     | PN   | 7.3       |
| M71            | Sagitta       | GC   | 8.0       |
| M107           | Ophiuchus     | GC   | 7.8       |
| M12            | Ophiuchus     | GC   | 6.7       |
| M10            | Ophiuchus     | GC   | 6.6       |
| M14            | Ophiuchus     | GC   | 7.6       |
| M9             | Ophiuchus     | GC   | 7.8       |
| M4             | Scorpius      | GC   | 5.4       |
| M80            | Scorpius      | GC   | 7.3       |
| M19            | Ophiuchus     | GC   | 6.8       |
| M62            | Ophiuchus     | GC   | 6.7       |
| M6             | Scorpius      | OC   | 4.2       |
| M7             | Scorpius      | OC   | 3.3       |
| M11            | Scutum        | OC   | 5.8       |
| M26            | Scutum        | OC   | 8.0       |
| M16            | Serpens       | Neb  | 6.0       |
| M17            | Sagittarius   | Neb  | 6.0       |
| M18            | Sagittarius   | OC   | 6.9       |
| M24            | Sagittarius   | SC   | 2.5       |
| M25            | Sagittarius   | OC   | 4.6       |
| M23            | Sagittarius   | OC   | 5.5       |
| M21            | Sagittarius   | OC   | 5.9       |
| M20            | Sagittarius   | Neb  | 6.3       |
| M8             | Sagittarius   | Neb  | 4.6       |
| M28            | Sagittarius   | GC   | 6.8       |
| M22            | Sagittarius   | GC   | 5.1       |
| M69            | Sagittarius   | GC   | 7.4       |
| M70            | Sagittarius   | GC   | 7.8       |
| M54            | Sagittarius   | GC   | 7.6       |
| M55            | Sagittarius   | GC   | 6.3       |
| M75            | Sagittarius   | GC   | 8.3       |
| M15            | Pegasus       | GC   | 6.3       |
| M2             | Aquarius      | GC   | 6.3       |
| M72            | Aquarius      | GC   | 9.3       |
| M73            | Aquarius      | OC   | 8.9       |
| M30            | Capricornus   | GC   | 7.3       |

**KEY:** DS = double star; GC = globular cluster; Gal = galaxy; Neb = nebula; SC = star cloud; OC = open cluster; PN = planetary nebula; SNR = supernova remnant



Like a visual Messier marathon, some preparation is required. Make sure your mount is well aligned. If your alignment is good enough, you may be able to skip plate solving and centering the target, which will save a significant amount of time.

If you're using sequencing software, make the sequence in advance and test it. You may want to rearrange some of the targets so you're not bouncing back and forth across the meridian, depending on where you are in the list.

If you're using a smart telescope, time how long it takes for it to find a target and start imaging so you can plan your night. It may well require more than one night to accomplish the whole list.

While some traditionalists may complain that part of the challenge of the Messier marathon is finding all the objects by hand, it's a different challenge to image so many targets in one or a few nights. Both the visual and astrophotography marathons are difficult and exciting.

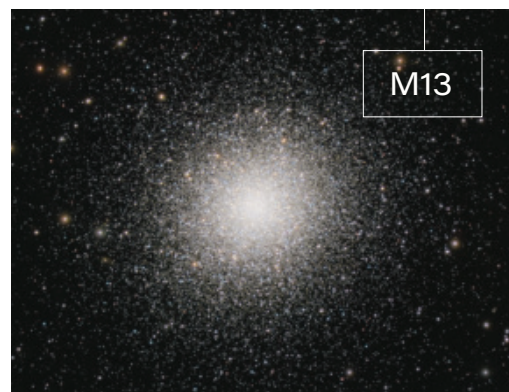
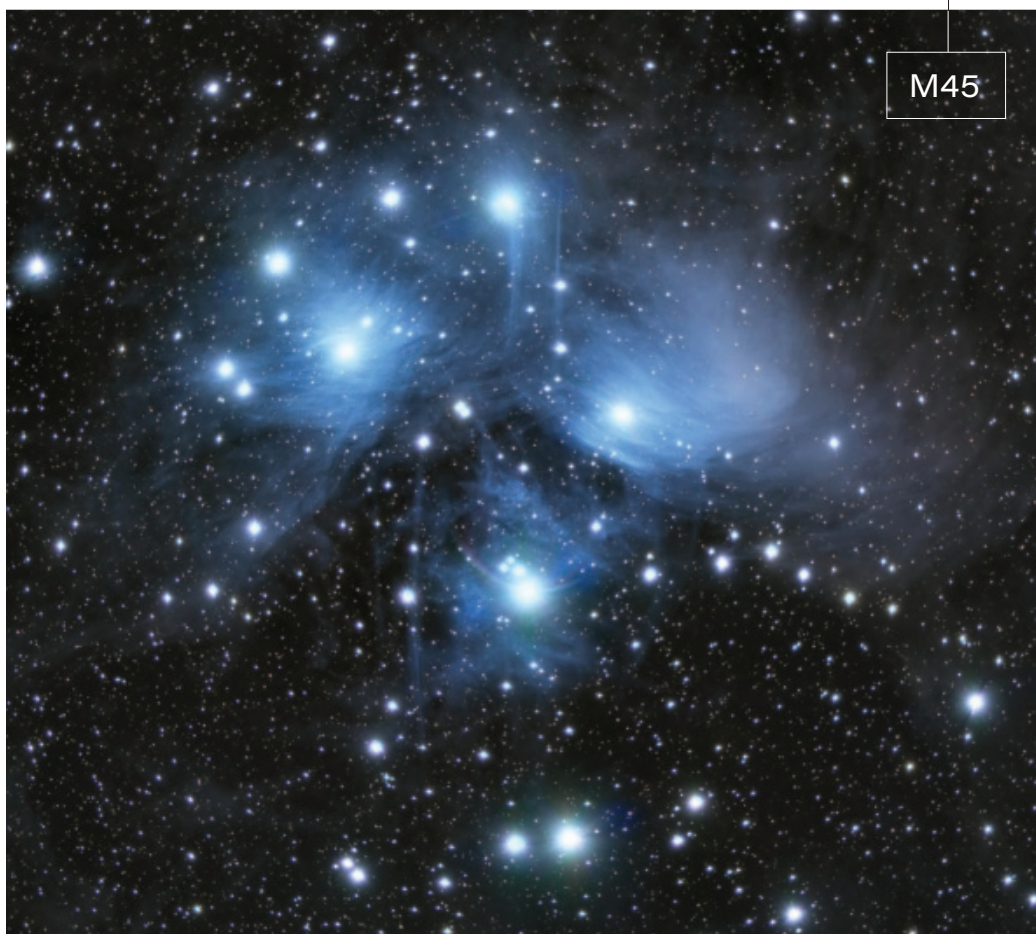
### On your mark ... get set ...

Running the Messier marathon isn't for the faint of heart — it's a challenge of one's stamina and observing skills. Whether you're imaging with an automated rig, using a go-to mount, or star-hopping your way around the sky, the challenge is also the thrill.

If the skies clear around the New Moon in March and you're ready to pull an epic all-nighter, get out there and rock the magnificent list of Charles Messier! 🍷

---

**Molly Wakeling** is an astro-imager who has participated in numerous Messier marathons, both visual and photographic.





# THE ART OF THE SINGLE-SHOT ASTROIMAGE

Here's how to carefully plan a single exposure to showcase your skill.

TEXT AND IMAGES BY SOUMYADEEP MUKHERJEE



The author captured this circumpolar star trail over desert salt flats from Kutch, India. **SPECS:** Nikon Z 6II camera; Nikon Z 24-120mm lens; 900-second exposure; f/1.4; ISO 1600



**NIGHTSCAPE ASTROPHOTOGRAPHY** combines the beauty of the night sky with gorgeous landscapes after dark. While some compositions can take hours to capture, with multiple tracked shots of the sky and multiple foreground images, you can simplify the process by using a single long-exposure image.

Incorporating both the sky and Earth, a single image can display the environment and showcase the raw beauty of the night, transporting those who look at it closer to a real-life experience. Single long-exposure (SLE) images are, in a sense, a projection of an astrophotographer's experience in the field. Read on to explore the technical as





A 15-minute exposure shows the National Large Solar Telescope at night. This solar observatory is situated at the banks of Pangong Lake, India, at an altitude of 14,100 feet (4,300 meters). **SPECS:** Nikon Z 6II camera; Samyang 135mm lens; f/5; ISO 1250

well as the philosophical side of single long-exposure images.

## Nightscape techniques

Nightscape astrophotography, or astro-landscape photography, can broadly be divided into four categories based on the techniques used to capture it:

1. **Untracked and single:** You capture a single image showing the night sky and the landscape.
2. **Untracked and stacked:** You place your camera on a tripod and take multiple images. These images are then stacked to improve the signal-to-noise ratio.
3. **Tracked and single:** You take a single

tracked image of the sky and an untracked image of the foreground to blend them together for the final result.

4. **Tracked and stacked:** You track the night sky with a star tracker and capture multiple images. This also requires a different set of foreground images (single or multiple), which are blended during processing.

There are also panorama images that capture multiple sections of the sky using any of the above-mentioned techniques. This article will mainly discuss the first option, “untracked and single.” But we’ll also see how “tracked and single” can be captured, with a twist.

## Single images go a long way

An SLE is not meant to capture the intricacy of the night sky. If you’re looking to get the best details of the Milky Way’s arms or a large nebula, track and stack your image. An SLE is meant to capture the environment. These images are what I call composition-heavy. While composition is important to all nightscape images, SLEs rely mostly on the overall shot, rather than its intricate details.

A photo of an automobile with the Milky Way or a historical monument with a constellation should tell a story — a story of Earth and sky at night. If

you are looking to document the region, the night sky, or simply want to convey how dark your night was, go with an SLE. And the best thing about this technique is that it's beginner-friendly.

## Plan and photograph: One click

Like any other nightscape images, SLE images need to be planned. That planning can either begin at home, with the help of apps like Photopills, Google Earth, etc., or by reaching the field early. Scouting the field in daylight (or even twilight) will give you an idea of your surroundings, which can be difficult to gauge at night. However, one advantage of SLE images is that you don't *have* to plan ahead. Just by looking at and feeling your surroundings, you can decide to set

up your camera and tripod and take an image.

While photographing the Milky Way, constellations, or asterisms with your camera on a tripod, if you don't want star trails in your shot, you are bound by the Rule of 500: The maximum allowed shutter speed should be 500 divided by your lens' effective focal length. For example, if you're using a 20mm lens on a full-frame camera, your maximum shutter speed would be  $500/20 = 25$  seconds. (If that same 20mm lens is on a crop-sensor camera, the effective focal length will longer by a factor of about 1.5, yielding a maximum shutter speed of  $500/30 = 17$  seconds.)

However, in order to get sharper stars, I would recommend using a different rule: the NPF rule. Here, N stands for

the f-number (or f/ratio) of your lens (f/2.8, f/4, etc.). P represents the pixel density, or how tightly the pixels are packed on your sensor. To find this number, divide the width of the sensor by the number of pixels along the width. Finally, F is the focal length of your lens. These values should all be in the same units (typically millimeters). The NPF formula is: maximum exposure (in seconds) =  $[(35 \times N) + (30 \times P)]/F$ . Choose an f/ratio (N), calculate your maximum exposure time before stars begin to trail, and choose your ISO. Try out different ISOs to see what level of noise is acceptable.

For SLE images, you can also use a star tracker at the  $\frac{1}{2}x$  sidereal rate. This will allow you to get a longer shutter speed (compared to the previous method of untracked), giving you a much cleaner image. However, the maximum shutter speed will now depend on the distance of your camera from the foreground subject. The farther the foreground object, the longer the shutter speed you can use.

If you are close to your foreground subject, tracking the image will blur it, even with a short shutter speed. You're better off shooting untracked in such cases. The tricky part for these images is that there are no rules to calculate the optimum shutter speed. I have tried exposing for 60 seconds with a 15mm lens and 20 seconds with a 50mm lens with no noticeable blur in the foreground. In both cases, the foreground subject was distant. Experiment with different shutter speeds to find the sweet spot, and be sure to note it for future reference.

If you're doing a star, planet, or Moon trail, there are no limits to your maximum exposure length. You can shoot for a few minutes or a few hours. But how do you pick the right settings? It's simple. Take a short test shot of four or five seconds with a high ISO through the lens' largest aperture. Tweak the ISO until you get the desired histogram curve. Now, adjust your shutter speed to the desired exposure, counting how many additional stops of light you are adding. (Each doubling of exposure length is an additional stop.) For each stop of exposure length you add, compensate by reducing ISO by one stop (a factor of two) or stopping down your aperture. Or, to make things really easy, put your current exposure details into an app like Exposure Calculator and adjust



Dual processing involves processing the same image twice, each time focusing on different aspects (e.g., the sky and then the foreground) and blending the two versions for the final image. This shows the night sky from the banks of Pangong Lake in India. **SPECS:** Nikon Z 6II camera; Nikon Z 20mm lens; 900-second exposure; f/4; ISO 800



Here, the Big Dipper appears in twilight over the mountains of Tash Rabat in Kyrgyzstan. This is a single image tracked at  $\frac{1}{2}x$  sidereal rate. **SPECS:** Nikon Z 6II camera; Sigma 50mm lens; 20-second exposure; f/1.4; ISO 1600





The Sagittarius arm of the Milky Way rises behind traditional Kyrgyz yurts at the banks of Song-Köl Lake.

**SPECS:** Nikon Z 6II camera; Sigma 50mm lens; 5-second exposure; f/1.4; ISO 8000





#### CLOCKWISE FROM TOP LEFT:

This creative composition shows the Sagittarius arm of the Milky Way captured through and beyond a crystal ball. **SPECS:** Sony a7 III camera; Zeiss 40mm lens; 13-second exposure; f/2; ISO 10000

This image shows the Milky Way's Sagittarius arm aligned with the statue of Yuri Gagarin at Barskoon Valley, Kyrgyzstan. **SPECS:** Nikon Zf camera; Nikon Z 14-24mm lens; 20-second exposure; f/2.8; ISO 3200

The author photographed Venus, the third brightest object in our sky, from the banks of Pangong Lake. **SPECS:** Nikon Z 6II camera; Samyang 135mm lens; 900-second exposure; f/4; ISO 640

This trail of a crescent Moon setting at midnight was captured from Kadiya Dhro, India. **SPECS:** Nikon Z 6II camera; Samyang 135mm lens; 900-second exposure; f/18; ISO 100





the aperture and ISO within the app until you get the desired exposure length.

## Compose strong, but simple

Remember what you're trying to show: the serene night sky and the place you are at. Your surroundings are as important as the starry night sky. Look around for the most interesting subject in the field. As a tool for storytelling and documentation, SLE images require a meaningful composition. Your foreground subject could be anything — a tree, a rock, a car, whatever.

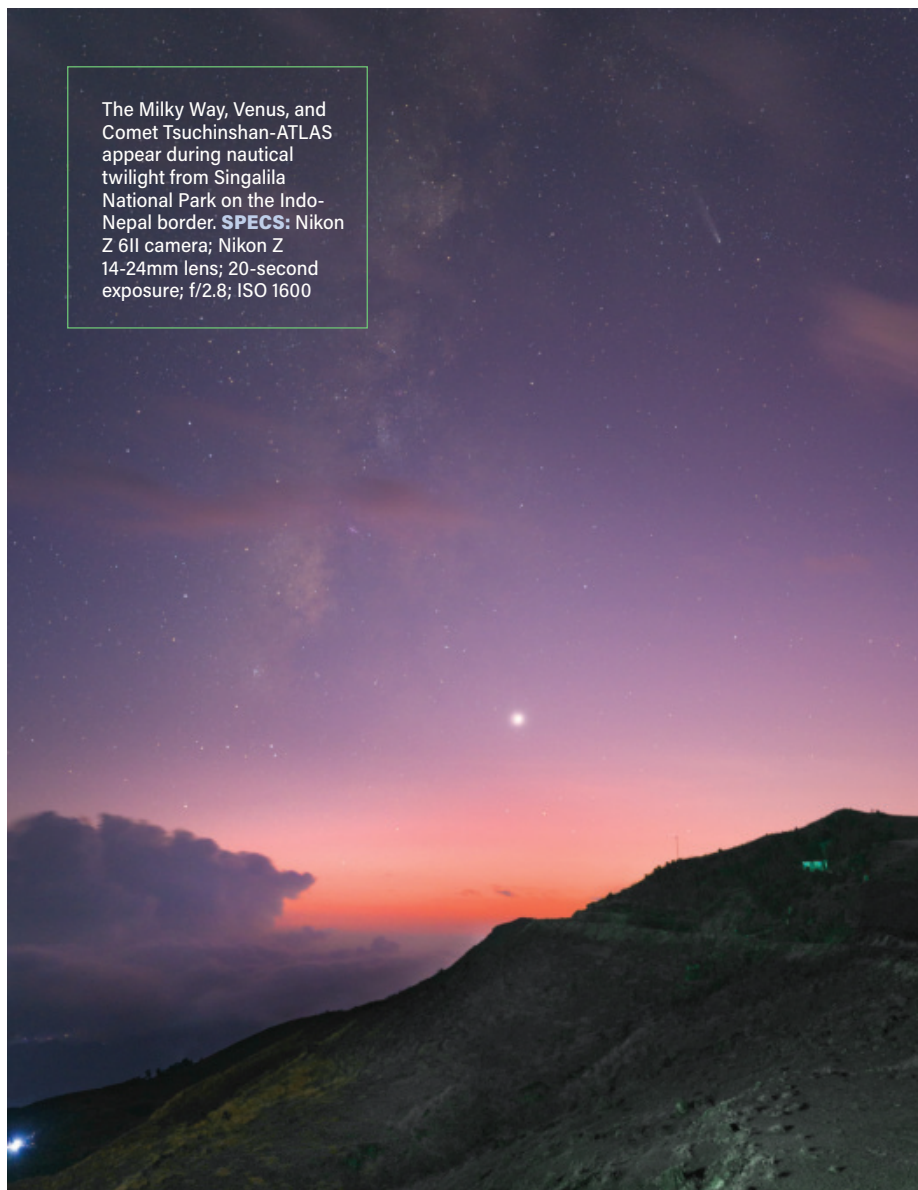
As far as the sky is concerned, start with a something big. Look for the Milky Way or large constellations like Scorpius, Ursa Major, or Orion. Smaller targets like a rising or setting Moon or even bright planets like Venus or Jupiter will also do the trick. While sharp stars convey a sense of calm, trailed stars convey a sense of movement. It's up to you how you'd like to portray your story.

## Processing

The last step in creating a mesmerizing SLE shot is processing. These images can be processed like others with Lightroom, Camera Raw, Photoshop, or any similar software. However, to bring out the best in SLEs, photographers employ a technique commonly used in landscape photography, known as “double-processing” or “dual-processing.” As the name suggests, the image is processed twice. The first time focuses on the foreground. Then the RAW image is again processed, focusing on the sky. These two versions are then blended together using a mask.

Always remember, to convey the true environment, the processing should be rather minimal. While this is not a rigid rule, minimal processing helps keep the image true, a key criterion for documentation and storytelling. Because you're taking a single exposure, there might be visible noise in your image. Modern cameras, however, are capable of handling extremely high ISOs and still producing a presentable image. Your processing can include careful noise reduction, but make sure your image doesn't get too soft. Remember, noise is not going to ruin your story. A little bit of it is no problem.

The Milky Way, Venus, and Comet Tsuchinshan-ATLAS appear during nautical twilight from Singalila National Park on the Indo-Nepal border. **SPECS:** Nikon Z 6II camera; Nikon Z 14-24mm lens; 20-second exposure; f/2.8; ISO 1600



## Nightscape imaging simplified

As amateur astronomers strive for more complex forms of nightscape imaging, with increasing difficulty and time, usage of multiple filters, and advanced processing techniques, SLE images sit quietly as an act of simplicity. The process of taking images becomes just you and the world under the stars. They capture the night as it unfolds in front of you, a story embedded in time. A simple click of your camera transforms into a document you can revisit years later. It is an image that nobody can reproduce, even from the same location. SLE images show the unique nature of the night sky, the coolness of the winds and the warmth of the stars. And, as an uncomplicated form of

nightscape photography, even beginners can enjoy success.

Your only worry in shooting long single exposures is the possibility that satellite trails will mess up your images. One approach to mitigate this is to shoot late at night, when Earth's shadow has covered much of the sky and sunlight doesn't reflect off satellites overhead.

In a way, single images are a tool for honest storytelling and documentation, standing far from composites. A simple composition, one click of the camera, and minimal processing is all you need. Because sometimes, less is more. ☾

---

**Soumyadeep Mukherjee** is an amateur astrophotographer, astrophotography educator, and writer from Kolkata, India.

Observable Space's CDK 14 is a Corrected Dall-Kirkham design with a focal ratio of  $f/7.2$ . OBSERVABLE SPACE.

STARRY BACKGROUND:  
ROMATHICHE/ADÖBE STOCK



# Observable Space's CDK 14 can capture your cosmos

Superb optics, top-notch engineering, and a relatively small footprint make this scope a winner. **BY TONY HALLAS**

**TO MANY OF YOU**, Observable Space — formerly PlaneWave — needs no introduction. Starting as a breakaway from Celestron in southern California in 2006, PlaneWave was founded by Rick Hedrick and Joe Haberman. It has grown to become an international provider of telescopes from 12.5 inches to 1 meter in size. The most popular design is the Corrected Dall-Kirkham, which gives a flat field with no coma and no astigmatism across a large

circle of illumination at a relatively fast  $f$ /ratio, typically  $f/6.8$ .

I've had several PlaneWave/Observable Space scopes over the years, and I've watched as these telescopes evolved to what they are today. My latest is the CDK 14, a 14-inch Corrected Dall-Kirkham utilizing a large two-element corrector lens located in the primary baffle tube.

The CDK 14 is one of the sharpest telescopes that Observable Space makes. On nights of exceptional seeing, my

smallest stars look like they were made with an apochromatic refractor — they are mere pinpricks. This from a telescope with a focal length of 2,563 millimeters.

## By the numbers

The telescope's statistics are impressive. Its focal ratio is  $f/7.2$ , which is plenty fast for imaging. It has a huge 282 mm of back focus, meaning you can put just about anything between the scope and the camera. It weighs a modest 48 pounds (21.8 kilograms), so you don't need a huge mount. The mirror substrate is fused silica — which, unlike Pyrex, is thermally stable. The telescope maintains focus with typical temperature drops during the night. And all the mirrors are coated with enhanced aluminum.



The focus is so stable that I focus maybe once a week just to check it. With a proper cooldown (using three fans mounted to the back plate that blow air onto the back of the mirror), the focus goes back to the previous night's position. The telescope doesn't lose collimation no matter its orientation. I shoot several hours past the meridian, at which point the telescope is upside down — stars are still perfect.

Collimation is usually a scary proposition with most Cassegrains, but not the CDK 14 because the primary mirror has been aligned and fastened in place. All you need to do is adjust the spherical secondary until you have symmetrical “doughnuts” — slightly out-of-focus stars. And the collimation holds. I've not adjusted mine in more than a year.

## The perfect telescope?

Not quite. There are a few things you should know.

The first is the shroud. It tends to sag into the optical path. There are rods that you can buy that fasten to the front cage assembly that keep the cloth from sagging, but I made mine using long threaded bolts that I fastened to the front. Then I slid some tubing over the bolts. The shroud rides on top of the rods, keeping it out of the light path. But you also have to keep the shroud tight. I solved this by using long zip ties that I poked through the end of the shroud and fastened to the back of the scope. This keeps tension on the shroud.

The other issue is more serious: heating the primary when there's a lot of dew. For some reason, the small heating pads to accomplish this were fastened directly to the massive aluminum back plate. The idea was to gently heat the air around the mirror. Unfortunately, the back plate acts as a gigantic heat sink. It absorbs any heat generated, and it's exposed to the cold night air. End result: little heat ever reached the primary.

My solution was to remove the entire back mirror assembly to access the heating pads. I peeled them off and put some insulating material between them and the back plate. Now the pads' heat really does heat the air, which in turn heats the primary. It only takes one to two degrees above ambient to keep dew off the mirror. The back plate assembly is pin



The author took this image of the Ghost Nebula (vdB 141) through his Observable Space CDK 14 with a Player One Zeus camera. He chose the best 16 of twenty-five 900-second exposures through RGB filters. TONY HALLAS

## PRODUCT INFORMATION

### Observable Space CDK 14

**Aperture:** 14 inches

**Focal length:** 2,563 millimeters

**Focal ratio:** f/7.2

**Image circle:** 52 mm

**Mirror:** Fused silica

**Optical tube assembly:** Carbon fiber

**Length:** 35 inches (889 mm)

**Weight:** 48 pounds (21.8 kg)

**Price:** \$18,500

**Contact:** Observable Space

1375 N. Main St., Bldg. #1

Adrian, MI 49221

1-310-639-1662

[www.planewave.com](http://www.planewave.com)

between the aluminum and carbon fiber components. It helps maintain the accurate alignment of the optical elements.

## An absolute joy

Once I solved the two minor problems I mentioned, the telescope has been a real workhorse that operates night after night without complaint or error. It is seeing-limited under almost all conditions and can hold a variety of cameras, large or small.

In addition, it lets you shoot wider fields than bigger telescopes, but you can zoom in by using a camera with a smaller chip. More samples of what this telescope can do can be seen on my AstroBin page: [app.astrobin.com/u/tonyhallas](https://app.astrobin.com/u/tonyhallas).

In sum, the Observable Space CDK 14 is an observatory-class telescope that's a huge performer. It operates in a relatively small footprint and costs less than larger scopes. And being smaller, it reaches thermal equilibrium in less time than larger telescopes. Yet it provides a substantial focal length over a 52mm image circle with perfect stars. As an advanced imager, I demand the best from my equipment. The Observable Space CDK 14 delivers this and more. ☺

registered, which ensures correct alignment should removing it be necessary, for example, to clean the primary.

The other aspects of the telescope are wonderful. Observable Space created its own software to control the telescope. There are many ways you can set cooling and heating, either automatically or manually. If you have the massive focuser or rotator unit, you can control both from your computer. The focusing software is the best that I've ever used. Simply set your parameters and press “go.” In a matter of minutes, focus will be perfect.

A lot of the telescope is carbon fiber, which is thermally stable. Observable Space even incorporates an expansion joint, should there be any movement

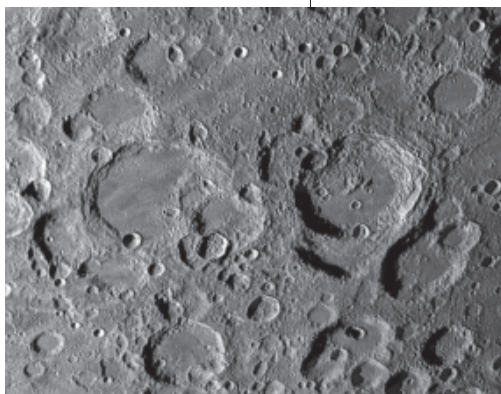
**Tony Hallas** is one of the world's foremost astroimagers and a contributing editor of Astronomy.

# Transparency and seeing

These two factors should be your first considerations for an imaging session.



These two views of the lunar region containing the craters Stofler and Maurolycus demonstrate the difference between poor seeing (left) and good seeing. ROBERT REEVES



As close as we astronomers love to feel to space, one thing stands between us and the outer reaches: Earth's atmosphere. More than 60 miles (97 kilometers) of gases separate us from the cosmos, and it has an effect on our ability to photograph and observe. Astronomers speak of two measures of atmospheric quality: transparency and seeing. Astronomical League observing programs often require you to record estimates of those conditions. So what are they?

## Transparency

Transparency is exactly what it sounds like: how clear the atmosphere is. Clouds, smoke, dust, and haze can obscure your view of celestial objects. You may decide not to attempt to observe or image on a given night if the transparency is poor enough.

Discerning transparency takes practice. The more you look up at your sky, the more you'll start to notice the differences between nights. One way to gauge the level of transparency (including light pollution) is to look at the Little Dipper. Its stars will give you a rough estimate of your limiting magnitude.

In magnitude 1 (the least transparent) skies, no stars in the Little Dipper are visible, including Polaris, meaning that it's probably cloudy. If you can only see Polaris (Alpha [ $\alpha$ ] Ursae Minoris), but no other stars of the Little Dipper, then your sky is at magnitude 2. If the two stars at the end of the Dipper's scoop are visible, that's magnitude 3. If you see any other stars in the handle,

then your sky is at magnitude 4. If you can make out either of the other two stars that form the scoop, that's magnitude 5. Finally, if you can see all seven stars in the Little Dipper, you've reached magnitude 6, about the limiting naked-eye magnitude. The more transparent the atmosphere is, the fainter the objects you'll see, and they'll be clearer and of higher contrast.

## Seeing

Seeing is less familiar. It's a measure of the steadiness of the atmosphere. The mix of warm and cold air causes our atmosphere to swirl, disrupting the path of light through it. Think about the roiling you see above a hot car or barbecue grill — the effect is the same. Seeing is influenced by both global weather patterns and localized conditions, all the way down to the ground under your feet and the interior of your telescope tube.

Good seeing is essential for high powers. Trying to discern small details on the Moon or split close double stars is impossible when the seeing is poor. Stars and objects in your images will be soft and blurred. The easiest way to determine your seeing conditions is to look at how rapidly the stars are twinkling. Seeing is usually measured on a scale of 1 to 5, with 1 being poor and 5 being excellent.

## Look ahead

Can we know in advance what the conditions might be like for a given night? Yes! Meteorological modeling and weather satellite imagery are used to estimate what the transparency and seeing will be as far ahead as the next several nights. My favorite app for astronomical weather forecasts is Astrospheric ([www.astrospheric.com](http://www.astrospheric.com)), which shows cloud cover, transparency, seeing, wind speed and direction, temperature, dew point, and much more, including maps of smoke. I also often use Clear Dark Sky ([www.cleardarksky.com](http://www.cleardarksky.com)) and Clear Outside (<https://clearoutside.com>).

Under transparent skies, drink in the beauty of nebulae and tease galaxies out of the background. And extended periods of excellent seeing are the best times to be at the eyepiece. We live for those clear, steady nights, but even if the conditions aren't stellar, go out and love the night sky anyway. ☾

**The more you look up at the sky, the more you'll start to notice the differences between nights.**



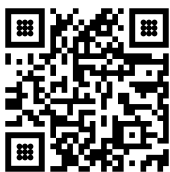
**BY MOLLY WAKELING**  
Molly is an avid astrophotographer active in STEM outreach. She has a Ph.D. in nuclear engineering.



BROWSE THE "OBSERVING BASICS" ARCHIVE AT  
[www.Astronomy.com/author/molly-wakeling](http://www.Astronomy.com/author/molly-wakeling)



## NEW PRODUCTS



Attention,  
manufacturers:  
To submit a product  
for this page,  
email [products@  
astronomy.com](mailto:products@astronomy.com).

### Red Sun DayStar Filters

DayStar's Sol 100 Hydrogen-alpha telescope is a 4-inch instrument that allows safe viewing of normally invisible solar features. The design offers a  $\frac{3}{4}^\circ$  field of view and unique coatings, optimizing the Sol 100 for the H $\alpha$  wavelength.

**\$4,995**  
**1-866-680-6563**  
**www.daystar.com**

### Both eyes open Celestron

Torrance, California

Celestron's Skymaster Pro ED 15x70mm Porro Binoculars feature front lenses made of extra-low-dispersion glass. These binoculars have a  $4.4^\circ$  field of view and 15.7mm of eye relief. The unit weighs 4.6 pounds (2.1 kilograms).

**\$349.95**  
**1-310-803-5955**  
**www.celestron.com**



### Spacey view Firefly Books

Richmond Hill, Ontario

If you've been following the JWST, you'll delight in *Webb's Cosmos: Images and Discoveries from the James Webb Space Telescope*, by professional astronomer Marcin Sawicki. This 304-page hardcover book contains more than 200 of JWST's images with explanations.

**\$49.95**  
**1-800-387-6192**  
**www.fireflybooks.com**

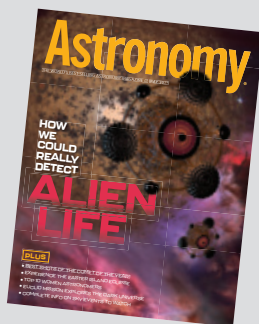
FROM THE LEFT: DAYSTAR FILTERS; CELESTRON; ASTRONOMY; MICHAEL E. BAKICH

## INDEX of ADVERTISERS

|                                        |       |
|----------------------------------------|-------|
| Bob's Knobs .....                      | 49    |
| Celestron .....                        | 60    |
| FireFly Books .....                    | 2     |
| Knightsware .....                      | 49    |
| Lazy Bear Expeditions .....            | 5     |
| Mason Capital Partners .....           | 11    |
| Metamorphosis Jewelry .....            | 49    |
| Oberwerk .....                         | 11    |
| Rainbow Symphony .....                 | 49    |
| Scope Buggy .....                      | 6     |
| Snow King Observatory & Planetarium .. | 6, 59 |
| Subscribe to Astronomy .....           | 13    |
| The Space Store .....                  | 17    |

The Advertiser Index is provided as a service to *Astronomy* magazine readers. The magazine is not responsible for omissions or for typographical errors in names or page numbers.

## Want more Astronomy?



Get your FREE weekly *Astronomy* newsletter delivered to your inbox!

## Astronomy

Go to  
[Astronomy.com/magazine/newsletter](http://Astronomy.com/magazine/newsletter)  
for more info.

## Deep-Sky Planner 9

Exceptional Planning & Logging software

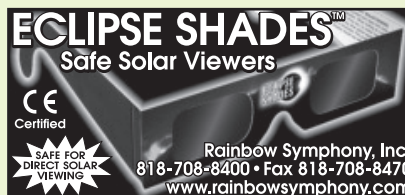
Download the free  
Trial Edition at

[www.knightware.biz](http://www.knightware.biz)

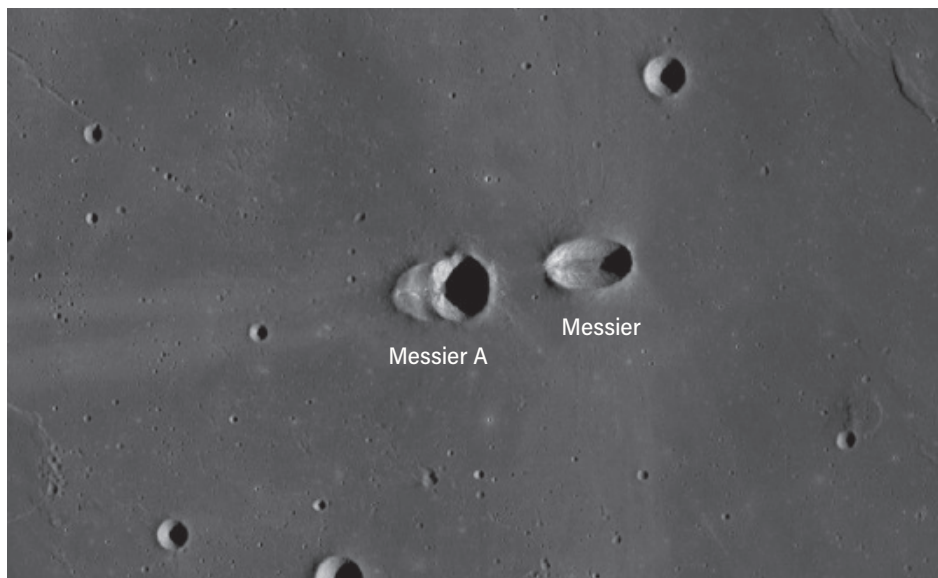
## Fine Meteorite Jewelry

In Gold &  
Platinum

[www.NinePlanetsRing.com](http://www.NinePlanetsRing.com)



MARKETPLACE



One theory for the creation of Messier and Messier A suggests that a projectile impacted the Moon at a very shallow angle, creating the elongated crater, then broke apart or ricocheted to create the double impact craters of Messier A.

NASA/GSFC/ARIZONA STATE UNIVERSITY

## Elongated craters

**Q** | WHY ARE CRATERS PERFECTLY ROUND EVEN THOUGH METEORITES ARE IRREGULARLY SHAPED?

*Frank Casella  
Ramsey, New Jersey*

**A** | To answer your question, let's have some fun. First, watch as I throw this irregularly shaped rock down at an angle onto a smooth mudflat. The rock strikes the flat and, in the process, splatters mud in all directions. Now let's venture over to the affected spot and examine the result: an elongated hole around the rock's impact point. The elongation is as much a result of the impact angle as of the rock's nonspherical shape. But notice the rock: Apart from being dirty and a bit the worse for wear, it has undergone no alteration from the impact.

Now, let's go to the Moon 108 million years ago. When a 5- to 6-mile-wide (8 to 10 kilometers) asteroid slammed into the lunar surface at a speed exceeding 45,000 mph (72,400 km/h), it vaporized on impact, along with much of the material within the impact area. Conditions in that region were fiery, but when the area cooled, the 53-mile-wide (85 km) hole that would one day be known as Crater Tycho remained. One of the Moon's most prominent features, note how elegantly circular it is — even though, as you point out, the asteroid that caused

it was likely irregularly shaped.

So, why does a rock striking mud form an elongated hole, while an oddly shaped asteroid produces a circle? Simply because the two formation processes are entirely different. Whereas a rock remains intact when it hits the mud, the asteroid vaporizes. It is the explosion, rather than the asteroid itself, that forms the crater. And since the material from the explosion is ejected equally in all directions, the resultant hole will almost always be circular and, on average, about 10 to 20 times the diameter of the body that formed it.

That having been said, you might find the occasional elongated crater, produced when an impactor strikes a surface at a very shallow angle. In this instance, the part of the asteroid touching the surface might have exploded, while the section at the other end was torn away and created a secondary impact, resulting in an elongated crater or a double crater. A good example is the elongated double lunar crater known as Messier and Messier A; planetary astronomers estimate that the body which produced this double crater might have struck the Moon at an angle of less than 5° relative to the lunar surface.

*Edward Herrick-Gleason,  
Astronomy Educator,  
St. John's, Newfoundland and Labrador*

**Q** | HOW DOES A BLACK HOLE GENERATE A MAGNETIC FIELD AND HOW CAN IT BE MEASURED AND VISUALIZED?

*Alan Croft,  
Seattle, Washington*

**A** | As black holes feed, they pull material into a disk around them. The material orbiting in this disk gets heated to extreme temperatures, and so it becomes a plasma — a state of matter in which some of the electrons are separated from their atoms. This creates ions, or atoms that become charged because the number of electrons and protons are no longer the same. So, there are both positively charged ions and negatively charged electrons in this plasma. As these charged particles move, they generate electric currents, which naturally lead to magnetic fields forming.

Electrons gyrating around magnetic field lines produce a type of emission at radio frequencies called synchrotron radiation, which we observe with the Event Horizon Telescope (EHT). Synchrotron radiation is inherently polarized: the radio waves oscillate in a





The Event Horizon Telescope released a polarized view of the supermassive black hole in M87 in 2021. The lines indicate the structure of the magnetic field in the bright accretion disk around the black hole. EHT COLLABORATION

specific direction prescribed by the geometry of the magnetic field line around which the electron was moving when it emitted this radiation. By imaging polarized light from hot glowing gas near black holes, we are directly inferring the structure and strength of the magnetic fields that thread the flow of gas and matter that the black hole feeds on and ejects.

So, polarized light teaches us about the astrophysics, the properties of the gas, and the mechanisms that take place as a black hole feeds! There is a lot of evidence that magnetic fields play a fundamental role in how a black hole feeds and ejects powerful jets of plasma. The process that launches these jets is the most energetic mechanism in the universe, and dramatically affects how galaxies grow, merge, and evolve. It is so striking that such large-scale damage can be caused by such a small object in the center of a galaxy, and it all starts in the plasma at the edge of the black hole, where these magnetic fields rule.

With the EHT, we have imaged the polarization structure around both the M87\* and Sagittarius A\* (Sgr A\*) black holes. M87\* and Sgr A\* are very different black holes. M87\* is quite a special black hole: It weighs in at 6 billion solar masses, it lives in a giant elliptical galaxy, and it ejects a powerful jet of plasma visible at

all wavelengths. Sgr A\*, on the other hand, is a more run-of-the-mill black hole: It is 4 million solar masses, it lives in our ordinary spiral Milky Way Galaxy, and it doesn't seem to have a jet at all. Yet, when we first imaged all the light coming from these black holes, the images looked strikingly similar. The dominating feature was the gravitational lensing of the light around the black hole shadow.

Essentially, the black hole's gravity is so immense that it bends the light of the portion of the accretion disk that is behind it around itself so that we can see behind the black hole. Looking at all the light from these two black holes, they were essentially the same. Looking at the portion of the light that is polarized, we expected to learn their magnetic fields have different properties — perhaps one is more ordered and strong, one is more disordered and weak. However, because they also look similar in polarized light, it is now quite clear that these two different classes of black holes have very

similar magnetic field geometry.

With the two polarized images of very different black holes, we now have compelling evidence that strong magnetic fields are ubiquitous. The next step now involves connecting that geometry to how these systems move, evolve, and flare. New projects like the

**WHY DOES  
A ROCK STRIKING  
MUD FORM AN  
ELONGATED  
HOLE, WHILE AN  
ODDLY SHAPED  
ASTEROID  
PRODUCES  
A CIRCLE?**

An observer on Mars could watch Earth transit the Sun on Nov. 10, 2084; the Moon will begin its solar crossing about four hours after Earth. Our planet will take almost 19 minutes to fully enter and fully exit the Sun, and will be visible in silhouette for more than eight hours. Earth and the Moon will appear 36" and 9" across, respectively, as they glide across the Sun's 21'-wide disk. *ASTRONOMY: TONYA LIMBERG*

next-generation EHT (ngEHT) and the Black Hole Explorer (BHEX) will open up new areas of study of black holes that will help unravel the mysteries of how black holes feed. The ngEHT plans to add more telescopes on Earth to fill in our Earth-sized virtual mirror and observe a lot more often. With these expansions of the EHT, we will be able to make polarized movies of black holes. We will directly observe the dynamics between M87\* and its jet. BHEX, on the other hand, aims to add a telescope in space to dramatically increase the resolution of the EHT. With this pioneering effort, we will be able to observe the sharp photon ring at the edge of the event horizon's shadow in images of black holes. This photon ring, which is created as light from the accretion disk orbits the black hole many times before finally escaping, encodes properties of the space-time around the black hole and can tell us a black hole's spin. How much black holes rotate (their spin) is believed to be directly connected to why magnetic fields near the black hole look the way they look and how they can launch jets. (See December 2025's Ask Astro for further explanation of jets.)

**Sara Issaoun**

*NASA Einstein Fellow, Harvard & Smithsonian Center for Astrophysics, Cambridge, Massachusetts*



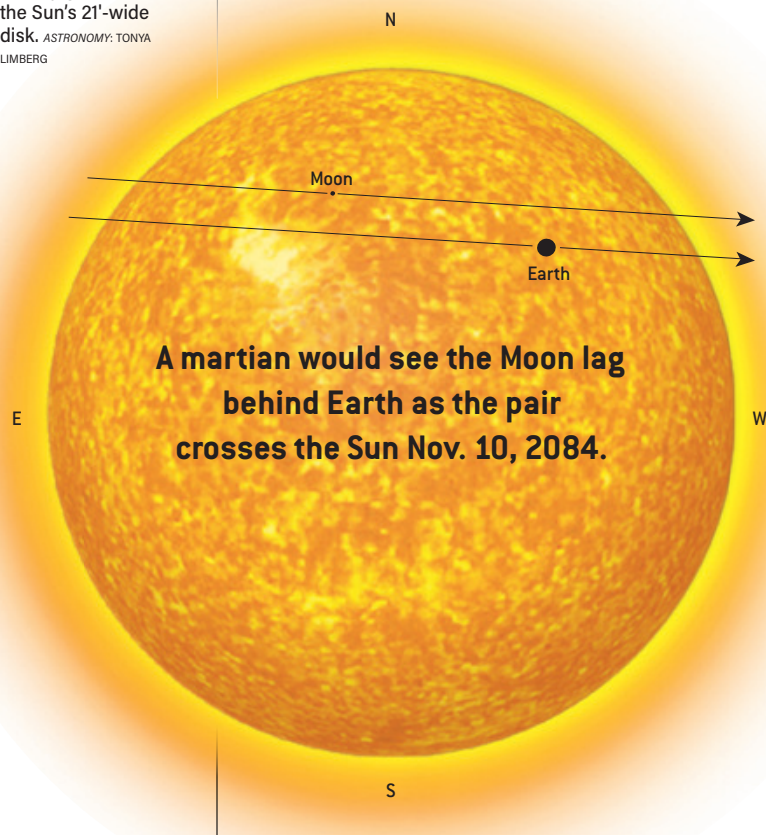
## Q | IF I WERE ON MARS, HOW OFTEN WOULD I SEE EARTH TRANSIT THE SUN?

**Steven Riser**  
*Conyers, Georgia*

**A** | From Mars, Earth transits the Sun four times in a 284-year cycle. The transits occur in either May or November at intervals of 100.5, 79, 25.5, and 79 years. During these events, Earth and the Moon would be seen as small black dots moving across the Sun's disk to someone using a properly filtered telescope.

We're now in the longest gap of this series. Science-fiction writer Arthur C. Clarke featured the last event — which occurred May 11, 1984 — in a 1971 short story, "Transit of Earth." In the tale, a fateful Mars mission's last surviving astronaut witnesses the transit before exhausting his air supply. Although Clarke was overly optimistic about human visits to Mars, astronauts — or long-lived rovers — may see the next Earth transit Nov. 10, 2084.

Earth transits have occurred only in May and November since the 17th century. This will continue into the next millennium. For a transit to occur, Mars, Earth, and the Sun must align when Mars lies near one of the points where its tilted orbit cuts through the







The Andromeda Galaxy has long been predicted to collide with our Milky Way in about 5 billion years; this illustration imagines the view as our neighbor looms large in Earth's skies. However, a paper published in the June 2025 issue of *Nature Astronomy* questioned the likelihood of that merger, depending on interactions with other Local Group galaxies. NASA; ESA; Z. LEVAY AND R. VAN DER MAREL, STSCI; T. HALLAS; AND A. MELLINGER

ecliptic — the plane of Earth's orbit. May transits occur when Mars passes beneath the ecliptic, at its orbit's descending node. November transits occur when Mars is near its ascending node, crossing the ecliptic from below. Because the Sun, Earth, and Mars align during a transit, Mars always is at opposition — and at its brightest for observers on Earth.

Earth in transit will appear smaller in martian skies (36") than Venus did from Earth in the June 2004 and 2012 transits (58"). Astronauts would need a telescope and appropriate solar filters to watch our planet glide across the Sun's face.

What makes Earth transits unique, however, is that each usually is accompanied by a transit of our Moon. Depending on the Moon's phase, it can either precede or follow Earth across the Sun. In rare cases, the Moon can transit so far ahead (Nov. 8, 1800) or so far behind (May 10, 2394) Earth that both bodies cannot be seen together on the Sun.

Seeing Earth and the Moon in transit would demonstrate dramatically just how large a gulf separates the two worlds — and for an astronaut on Mars, it also would be a reminder of how far away home really is.

**Francis Reddy**

Senior Science Writer, Astrophysics Science Division at NASA's Goddard Space Flight Center, Greenbelt, Maryland

## Q | HOW IS IT THAT GALAXIES MERGE AND COLLIDE BUT THE UNIVERSE IS EXPANDING AND EVERYTHING IS MOVING AWAY FROM EVERYTHING ELSE?

**Justin Hammersley**  
Sterling Heights, Michigan

**A** | Whether or not galaxies merge depends on how strong the gravitational attraction is between the galaxies and whether the universe's expansion is more powerful than gravity. Gravity affects everything in the universe. The Milky Way Galaxy is gravitationally pulling on NGC 3370, nearly 100 million light-years away. The catch, however, is that the gravitational attraction between the Milky Way and NGC 3370 is so tiny that the universe's expansion can overcome it.

Over small scales, the force of gravity can beat out cosmic expansion and hold structures together, such as galaxy groups and galaxy clusters. Our Local Group of galaxies is an example of a grouping held together by mutual gravitation. And actually, the gravitational attraction between the Milky Way and the Andromeda Galaxy is strong enough that we're moving toward each other and may collide in some 5 billion years.

**Liz Kruesi**

Science Journalist and Editor, Boulder, Colorado

## SEND US YOUR QUESTIONS

Send your astronomy questions via email to **askastro@astronomy.com**. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.





#### 1. A KITCHEN STAPLE

The Medulla Nebula (LBN 576) is a supernova remnant 11,000 light-years distant in Cassiopeia; its appearance has also earned it the nickname of the Garlic Head Nebula. The imager took 18.5 hours of exposure with a 5-inch scope at f/5.8 with a one-shot color camera and H $\alpha$ /OIII dual-band filter.

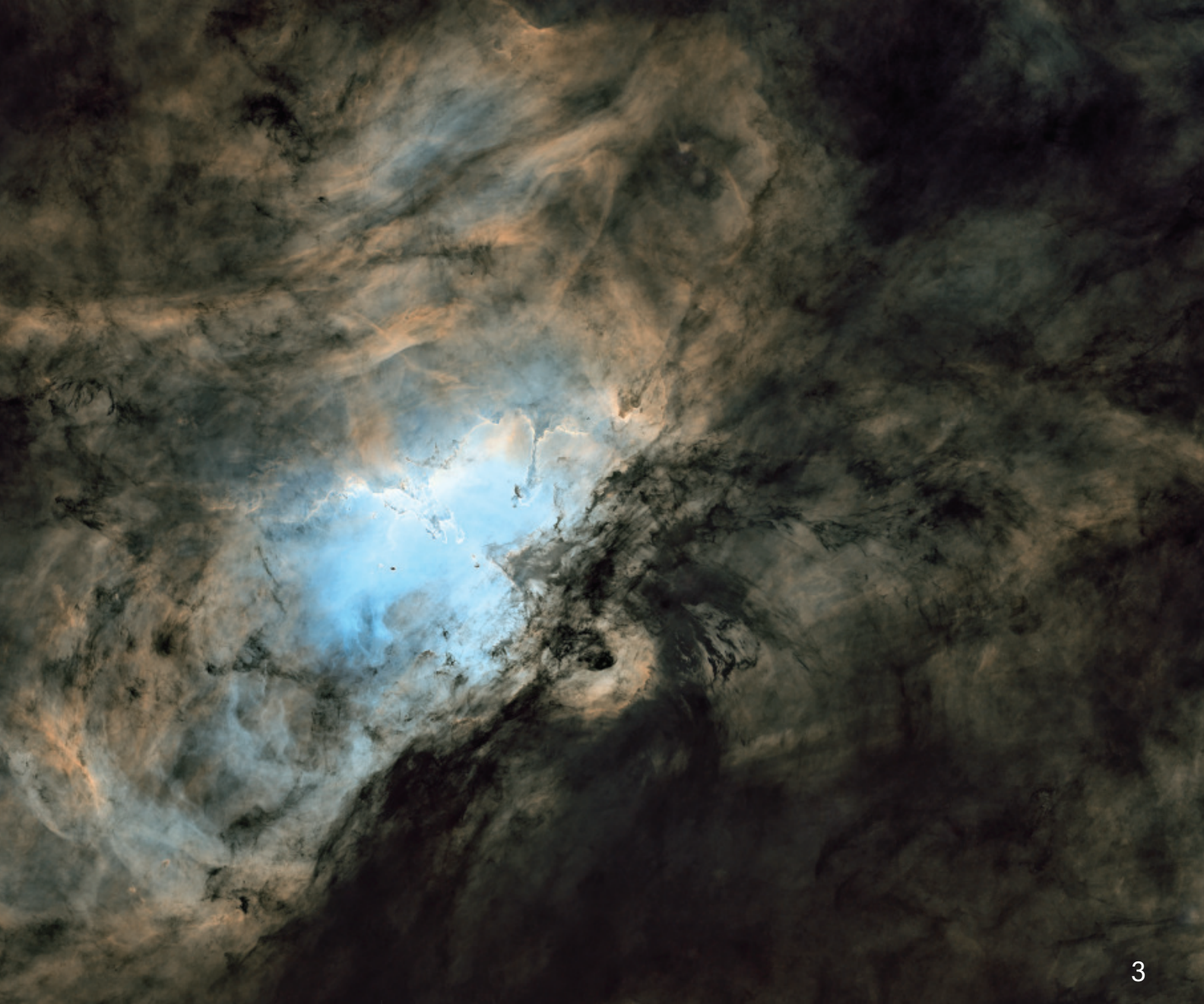
• *Luigi La Bella*

#### 2. A STELLAR STREAM

The edge-on Splinter Galaxy (NGC 5907) hosts a faint stream of stars, captured in this deep LRGB image consisting of around 12.5 hours of exposure taken with 20- and 12-inch remote scopes in Spain. The feature is what remains of a dwarf satellite galaxy that merged with the Splinter at least 2.5 billion years ago.

• *Alessandro Carrozzì*





3

### 3. THE EAGLE'S NEST

The Eagle Nebula (M16) is one of the most famous deep-sky objects and home to the iconic Pillars of Creation. This starless Hubble-palette rendition, taken over 58 hours with a 6-inch scope, emphasizes the dark nebulae that surround it. • **Fernando Oliveira de Menezes**

### 4. LOST IN FOG

While the Andromeda Galaxy is the closest *major* galaxy to the Milky Way, the irregular dwarf galaxy NGC 6822 — also known as Barnard's Galaxy — is an even closer independent galaxy. It lies just 1.6 million light-years away, gravitationally unbound to the Milky Way. It can be tough to observe, however, as it lies in Sagittarius, in the plane of the Milky Way. This image captured over two hours with an 11-inch f/2.2 RASA scope shows wisps of galactic cirrus — wisps of cold dust in our own galaxy. • **Chris Schur**



4



**5. RIVER OF LIGHT**

The Milky Way arcs above the valley of the Tua River in northern Portugal in this tracked panorama. The photographer used an astromodified Canon mirrorless camera at ISO 6400 and a 28mm lens at f/2.2, blending exposures of the ground (fourteen panels of 120-second exposures), sky (nine panels of ten 30-second exposures), and the Milky Way in H $\alpha$  (three panels of six 120-second exposures).

• *José Rodrigues*







#### 6. STARBIRTH IN THE KEEL

NGC 3503 in Carina is a stellar nursery surrounded by ghostly tendrils of gas and dust. At bottom right is the open cluster NGC 3532. The image comprises just over 17 hours of SHORGB data taken with a 4-inch f/5.5 scope.

• **Gerardo N. Rigioli**

#### 7. EMPIRE STATE OF SHINE

A Harvest Moon rises behind the Empire State Building on the evening of Oct. 6, 2025, captured with a Canon mirrorless camera and 150–600mm zoom lens.

• **David Gluchowski**



**SEND YOUR  
IMAGES TO:  
readergallery@  
astronomy.com.**

Please include the date and location of the image, your mailing address, and complete photo data: telescope, camera, filters, and exposures.





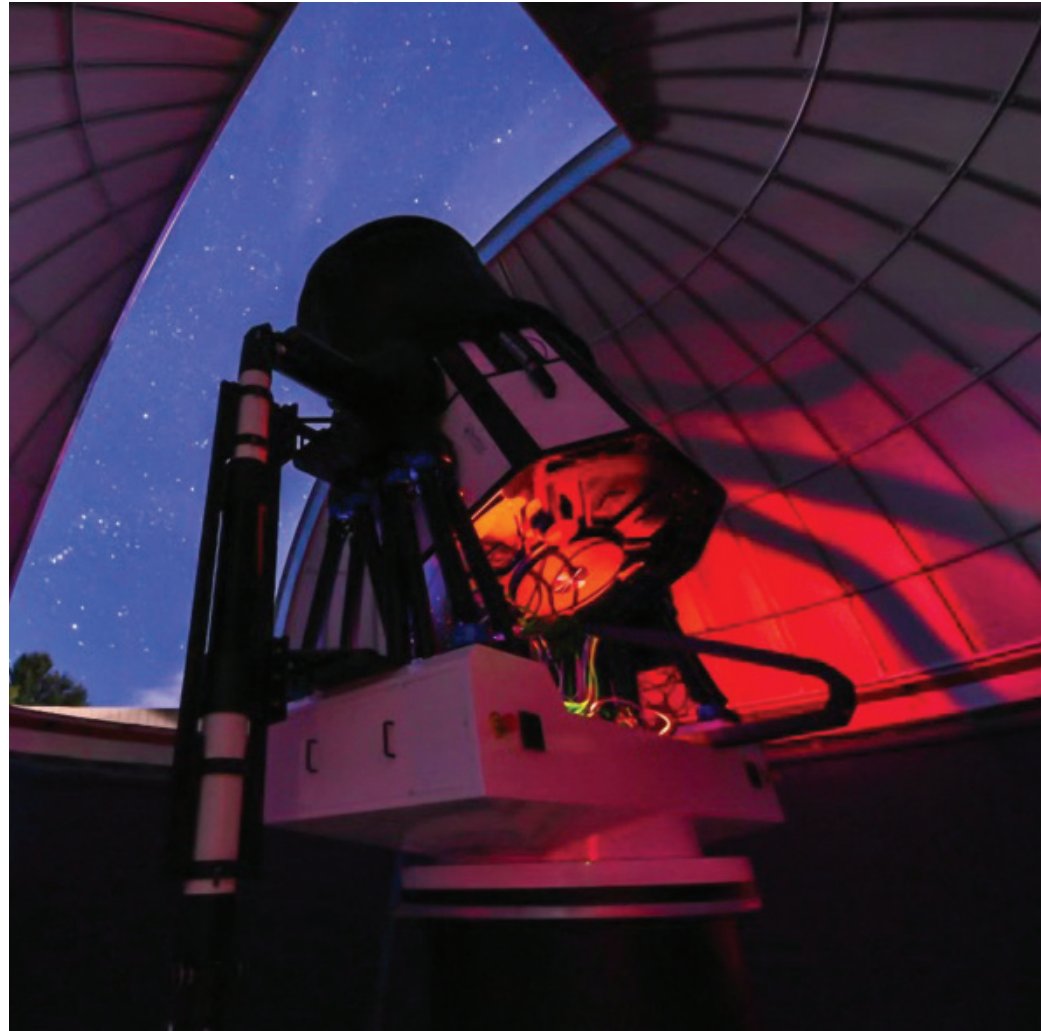
## A WHIRLPOOL OF STAR FORMATION

The Virgo Cluster holds literally thousands of galaxies, many of which are big, bright, and beautiful. NGC 4535 checks two of these boxes. With a diameter roughly equal to the Milky Way's, it ranks among the larger galaxies in the local universe. And this Hubble image leaves no doubt as to its visual splendor. But the galaxy lies nearly face-on to Earth and has a low surface brightness, making it a challenge to see through small telescopes. This led American amateur astronomer Leland Copeland to dub it the "Lost Galaxy" in the 1950s. Fortunately, Hubble's 2.4-meter mirror has no trouble revealing NGC 4535's delicate spiral arms, chock-full of bright blue star clusters and the pink emission nebulae that give birth to them. ESA/HUBBLE & NASA, F. BELFIORE, J. LEE AND THE PHANGS-HST TEAM



# SNOW KING

## OBSERVATORY & PLANETARIUM



Come explore the night sky at the King this winter and combine your stargazing experience with a spectacular meal at the Aurora restaurant overlooking Jackson Hole, WY.

[www.skobservatory.com](http://www.skobservatory.com)





# StarSense Explorer™

## The Smartest Way to Start Stargazing

Exploring the night sky has never been this easy. StarSense Explorer uses your smartphone and patented sky recognition technology to lead you to planets, nebulae, galaxies, and more—no experience required.

With a range of StarSense Explorer telescopes to choose from, there's an option for every budget and observing goal.

- 1 DOCK**  
YOUR SMARTPHONE
- 2 LAUNCH**  
THE STARSENSE  
EXPLORER APP
- 3 OBSERVE**  
STARS, PLANETS & MORE



Discover more at [celestron.com/sse](http://celestron.com/sse)



StarSense Explorer 150 mm  
Tabletop Dobsonian



StarSense Explorer DX 102AZ  
Refractor



StarSense Explorer DX 5"  
Schmidt-Cassegrain



StarSense Explorer 12"  
Dobsonian



StarSense Explorer 8"  
Dobsonian



StarSense Explorer LT 114AZ  
Newtonian

### CELESTRON PREMIER SELECT DEALERS

B&H Photo - 800.947.9970 - [bhphotovideo.com](http://bhphotovideo.com)

High Point Scientific - 800.266.9590 - [highpointscientific.com](http://highpointscientific.com)

Astronomics - 800.422.7876 - [astronomics.com](http://astronomics.com)

Woodland Hills - 888.427.8766 - [telescopes.net](http://telescopes.net)

Adorama - 800.223.2500 - [adorama.com](http://adorama.com)

Mile High Astronomy - 877.279.5280 - [milehighastro.com](http://milehighastro.com)

Focus Camera - 800.221.0828 - [focuscamera.com](http://focuscamera.com)

Agema AstroProducts - 562.215.4473 - [agemaastro.com](http://agemaastro.com)

Orange County Telescopes - 888-471-9991 - [octelescope.com](http://octelescope.com)



## May 2026

# Saturn returns to prominence

» The evening sky presents quite a show this month. The bright planets Venus and Jupiter shine prominently in the northwest as the sky darkens.

It's best to look for **Venus** first. The brilliant planet shines at magnitude  $-3.9$  but still lies in twilight. Fortunately, the inner world continues to move away from the Sun and thus appears slightly higher in the sky with each passing day.

It makes a fine sight below Orion the Hunter at the start of the month. As the planet slides eastward relative to the background stars during May, it reaches Gemini the Twins and approaches Jupiter by month's end. On the 31st, a telescope reveals Venus' 13"-diameter disk and 80-percent-lit phase.

Look higher in the sky and you'll easily see magnitude  $-1.9$  **Jupiter**. The giant planet also moves eastward relative to the starry backdrop, but at a much slower pace than Venus. This brings it closer to the horizon from one week to the next.

A telescope shows nice detail in the gas giant's atmosphere, particularly during moments of good seeing. In mid-May, Jupiter's equator spans 34" while its polar diameter is 2" less. This polar flattening arises from the planet's rapid rotation and gaseous nature. Also keep an eye out for Jupiter's four bright moons — Io, Europa, Ganymede, and Callisto — as they change positions from night to night.

The other three naked-eye planets line up in the eastern sky before dawn in early May. **Mercury** lies closest to the horizon. It stands  $5^\circ$  high 45 minutes before sunrise but should show up easily if you have an unobstructed view because it shines brightly at magnitude  $-0.8$ . Saturn and Mars appear above Mercury and point toward it. The inner planet shows a nearly full disk that measures 5" across when viewed through a telescope.

Mercury reaches superior conjunction May 14 and returns to the western evening sky near month's end. A line from Jupiter through Venus then aims to the innermost planet. Similar to its morning appearance, Mercury appears bright but low in the sky. A scope shows its 6"-diameter gibbous disk.

Back in the morning sky, **Mars** maintains its steady eastward progress against the stellar background. Its relatively quick motion nearly keeps pace with the Sun, however, so it doesn't gain a lot of altitude. On May 31, it appears about  $15^\circ$  high an hour before sunup and shines at magnitude 1.3. Through a telescope, Mars presents a bland disk measuring just 4" across.

Because **Saturn** orbits farther from the Sun than Mars, it moves much more slowly relative to the distant stars and thus gains more distance from our star and also extra altitude in the predawn sky. By the end

of May, it rises before 3 A.M. local time and climbs  $35^\circ$  high at the start of twilight. Glowing at magnitude 0.8, the ringed world easily outpaces the stars of its host constellation, Cetus the Whale.

Wait until Saturn climbs well above the horizon before targeting it with your telescope. As May winds down, you'll be rewarded with a stunning view of the planet's 17"-diameter disk and a ring system that spans 38" and tilts  $8^\circ$  to our line of sight. Also look for 8th-magnitude Titan, Saturn's largest moon, and a trio of 10th-magnitude satellites.

## The starry sky

Scan high in the west after darkness falls and your eyes will land on the constellation Pyxis the Compass. French astronomer Nicolas Louis de Lacaille introduced this obscure constellation in the 1700s, and it is often associated with the ship Argo. Lacaille divided the great sailing vessel into Carina the Keel, Vela the Sails, and Puppis the Stern, but did not formally include Pyxis in the partition. In the 19th century, John Herschel suggested replacing Pyxis with a constellation he called Malus the Mast, assigning it as part of the structure of Argo. The name did not last, however, and we still have Pyxis.

Something else that did not last is a constellation Johann Bode introduced in 1801 when he produced his celebrated

*Uranographia* star atlas. Around the southern and eastern parts of Pyxis, Bode created Lochium Funis, the Log and Line.

The Log and Line has a connection with Pyxis because both were used for navigating at sea. While a compass indicates the direction of travel — in relation to Earth's magnetic field — the log and line helped measure a ship's speed. A sailor threw a wooden object (the log) into the sea, and a line attached to it then slid through a crew member's hands. With knots tied at regular intervals along the line, sailors could count the number of knots that passed through his hands over a set period. This technique gave rise to speed being measured in knots, a unit that survives today. One knot indicates a speed of one nautical mile per hour.

On Bode's *Uranographia*, the astronomer drew the log of Lochium Funis to the east of the stars that make up the body of the compass, which he showed inside a box. The log includes Epsilon ( $\epsilon$ ) and Lambda ( $\lambda$ ) Pyxidis. The majority of the line appears south of the box, with many turns in it so it includes a number of faint stars.

In a way, it's a pity that Lochium Funis did not survive. Often, inclusions of certain objects can open a window into history, in much the same way as collecting stamps can reveal a lot about the world. ♠

# STAR DOME

## HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. May 1  
8 P.M. May 15  
7 P.M. May 31

Planets are shown at midmonth

## MAP SYMBOLS

- Open cluster
- ⊕ Globular cluster
- Diffuse nebula
- ⊕ Planetary nebula
- Galaxy

## STAR MAGNITUDES

- Sirius
- 0.0    ● 3.0
- 1.0    ● 4.0
- 2.0    ● 5.0

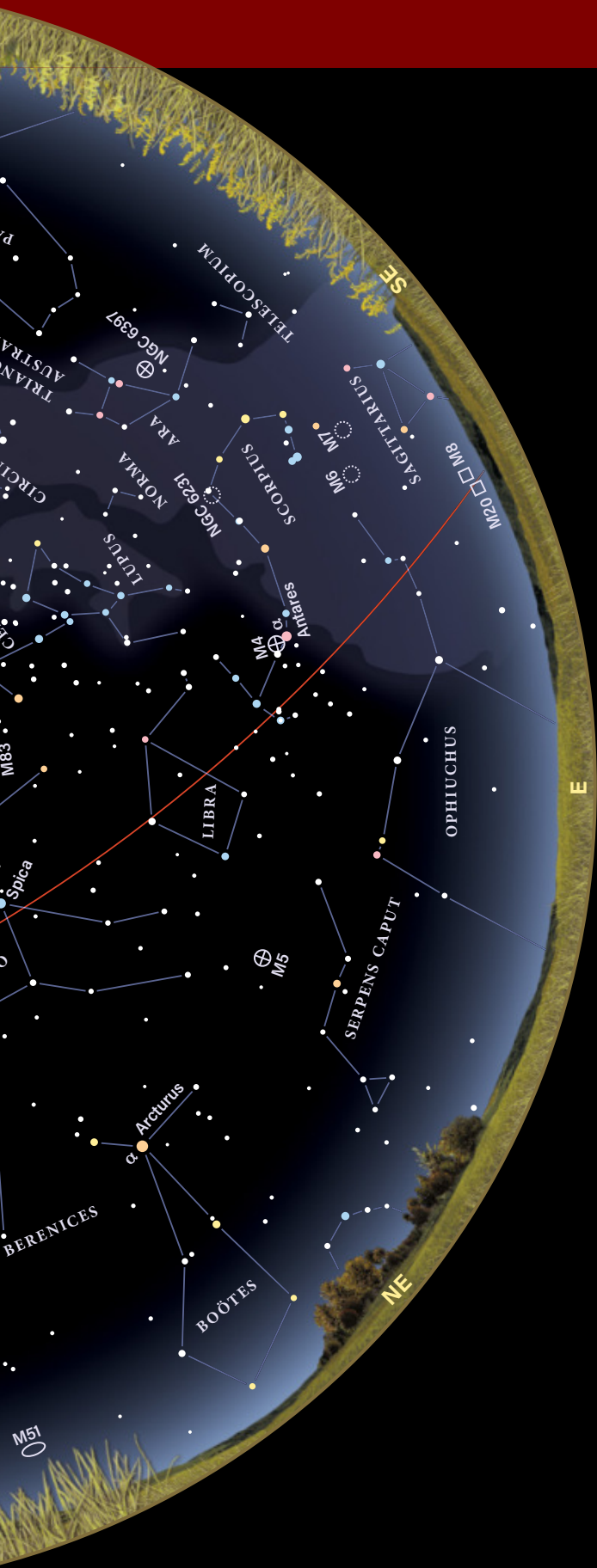
## STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light







## MAY 2026

| SUN.                                                                                    | MON.                                                                                    | TUES.                                                                                     | WED.                                                                                      | THURS.                                                                                    | FRI.                                                                                      | SAT.                                                                                      |
|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
|                                                                                         |                                                                                         |                                                                                           |                                                                                           |                                                                                           | <br>1  | <br>2  |
| <br>3  | <br>4  | <br>5  | <br>6  | <br>7  | <br>8  | <br>9  |
| <br>10 | <br>11 | <br>12 | <br>13 | <br>14 | <br>15 | <br>16 |
| <br>17 | <br>18 | <br>19 | <br>20 | <br>21 | <br>22 | <br>23 |
| <br>24 | <br>25 | <br>26 | <br>27 | <br>28 | <br>29 | <br>30 |
| <br>31 |                                                                                         |                                                                                           |                                                                                           |                                                                                           |                                                                                           |                                                                                           |

ILLUSTRATIONS BY ASTRONOMY BOEN KELLY

**Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.**

## CALENDAR OF EVENTS

- 1  Full Moon occurs at 17h23m UT
- 3 Venus passes 7° north of Aldebaran, 7h UT
- 4 The Moon passes 0.5° south of Antares, 3h UT  
The Moon is at apogee (405,839 kilometers from Earth), 22h30m UT
- 6 Eta Aquariid meteor shower peaks
- 8 Pluto is stationary, 11h UT
- 9  Last Quarter Moon occurs at 21h10m UT
- 13 The Moon passes 4° north of Neptune, 9h UT  
The Moon passes 6° north of Saturn, 22h UT
- 14 Mercury is in superior conjunction, 14h UT
- 15 The Moon passes 5° north of Mars, 1h UT  
Dwarf planet Ceres is in conjunction with the Sun, 3h UT
- 16  New Moon occurs at 20h01m UT
- 17 The Moon is at perigee (358,075 kilometers from Earth), 13h44m UT
- 19 The Moon passes 3° north of Venus, 2h UT
- 20 The Moon passes 3° north of Jupiter, 13h UT
- 22 Uranus is in conjunction with the Sun, 14h UT
- 23 The Moon passes 0.08° south of Regulus, 7h UT  
 First Quarter Moon occurs at 11h11m UT
- 31  Full Moon occurs at 8h45m UT  
The Moon passes 0.4° south of Antares, 9h UT

# EXPLORE THE UNIVERSE



Visit [TheSpaceStore.com](http://TheSpaceStore.com) today for high-quality astronomy products, many curated by the *Astronomy* magazine team.

- Custom-produced globes, as well as others from top manufacturers.
- Books and DVDs covering solar eclipses, observing guides, the cosmos and more.
- Magazines bringing you the latest astronomical discoveries and events.
- Collectible items to commemorate historic launches.
- Toys and games-have fun learning about astronomy!
- And much more!



**space<sup>®</sup>**  
**STORE**

Shop now at:  
**TheSpaceStore.com**

Sales tax where applicable.